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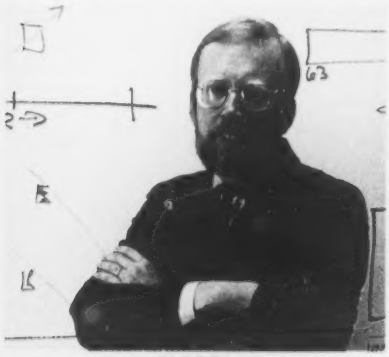
The new semiconductor superstars of Silicon Valley?

MANAGING TECHNOLOGY
Simulation

Electronic Business

VOL. 13, NO. 16 AUGUST 15, 1987

FOR THE MANAGEMENT TEAM IN ELECTRONICS, COMPUTER AND SYSTEMS COMPANIES



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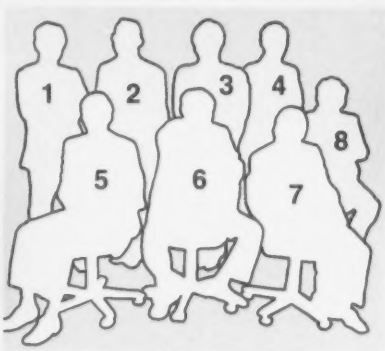

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ON THE COVER

Pictured left to right, standing, are: **1. Alex Au**, president and chief executive of Vitelic Corp.; **2. John G. Adler**, president of Adaptec Inc.; **3. Bob Swanson**, president and chief executive of Linear Technology Corp.; **4. Rodney Smith**, president and chief executive of Altera Corp. Seated are, from left: **5. Arthur J. Collmeyer**, president of Weitek Corp.; **6. Gary P. Kennedy**, president of Orbit Semiconductor Inc.; **7. Chan Desaigoudar**, chairman and chief executive of California Micro Devices Corp.; and **8. B.K. Marya**, chairman and president of Catalyst Semiconductor Inc.

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Cover photo: Liane Enkelis

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BPA ABP

The good old days may be back for computers

Remember when the computer industry used to outperform the economy? It's doing it again

After dropping slowly but inexorably for the second half of 1985 and all of 1986, the industrial production of computers and office machines (SIC 357) is rebounding smartly this year. Production in the second quarter already matched the level of the previous high, reached two years earlier in 1985, and was up 7% over the year-earlier level, for the second quarter of 1986, which also had the dubious distinction of being the previous low.

Cahners Economics forecasts that production should continue growing from here on, so much so that the second half, says economist Cheryl Patstone, may end up more than 8% ahead of the same period last year. This may signal a return to the days when the computer industry used to easily outperform the rest of the U.S. economy. Indeed, for 1987, Cahners Economics forecasts a growth of 6% for the industrial production of computers and office machines, against 4% for overall U.S. industrial production. For 1988, Patstone forecasts a 14% increase, twice the growth Cahners expects for the overall industrial production.

This is closer to the kind of performance the U.S. computer industry has been used to in the past, but it may not last much longer. In the decade from 1977 to 1986, the share represented by SIC 357 production has more than doubled, from 3% of total U.S. industrial production to 6.2%. By comparison, the share by the erstwhile all-American SIC 371 (motor vehicles and parts) has eroded in the same 10-year period from 5.4% to 4.8%. Therefore, as computers begin to account for a larger portion of industrial activity in the United States, their contribution to overall growth will increase and it will become harder for them to pull far ahead of the economy.

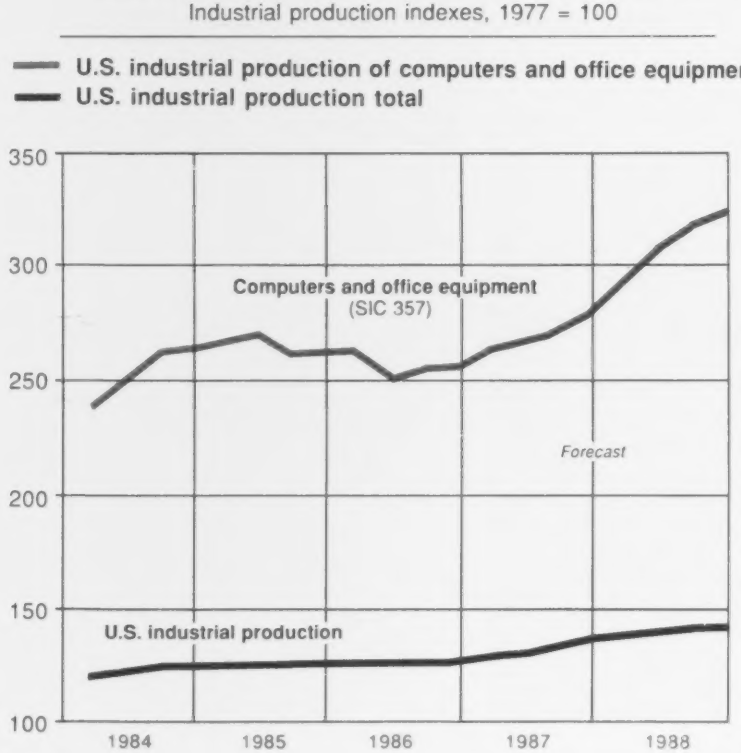
Even though at this writing the second-quarter revenue figures for individual companies were not yet available, it is clear from first-quarter results that the growth is coming from small systems. IBM's revenue for that period was up 5.5% over last year's quarter. As has been the case with IBM throughout the past two years, most of this increase came from sales outside the United States, which IBM fulfills usually from production plants located also abroad. Therefore, IBM's contribution to the growth of U.S. production has not been great, a fact reflected in the paltry 1% that industrial production for SIC 357 gained in the first quarter. On the other hand, Big Blue's much smaller but active PC rival Apple Computer Inc. grew by 41% in the first quarter. However, Apple's revenue amounted to only 5% of IBM's, and its production is increasingly based in the Far East. A larger contribution to U.S. industrial production may be coming from workstation manufacturers Apollo Computer and Sun Microsystems, which grew by 50% and 146%, respectively, in the first quarter. Their combined revenue amounts to less than half of Apple's, but most of this is generated by workstations produced in the United States.

One of the sources of growth, IBM hopes, is in the activity of computer manufacturers, even if many of them are competitors.

ALBERTO SOCOLOVSKY

Computers and office equipment

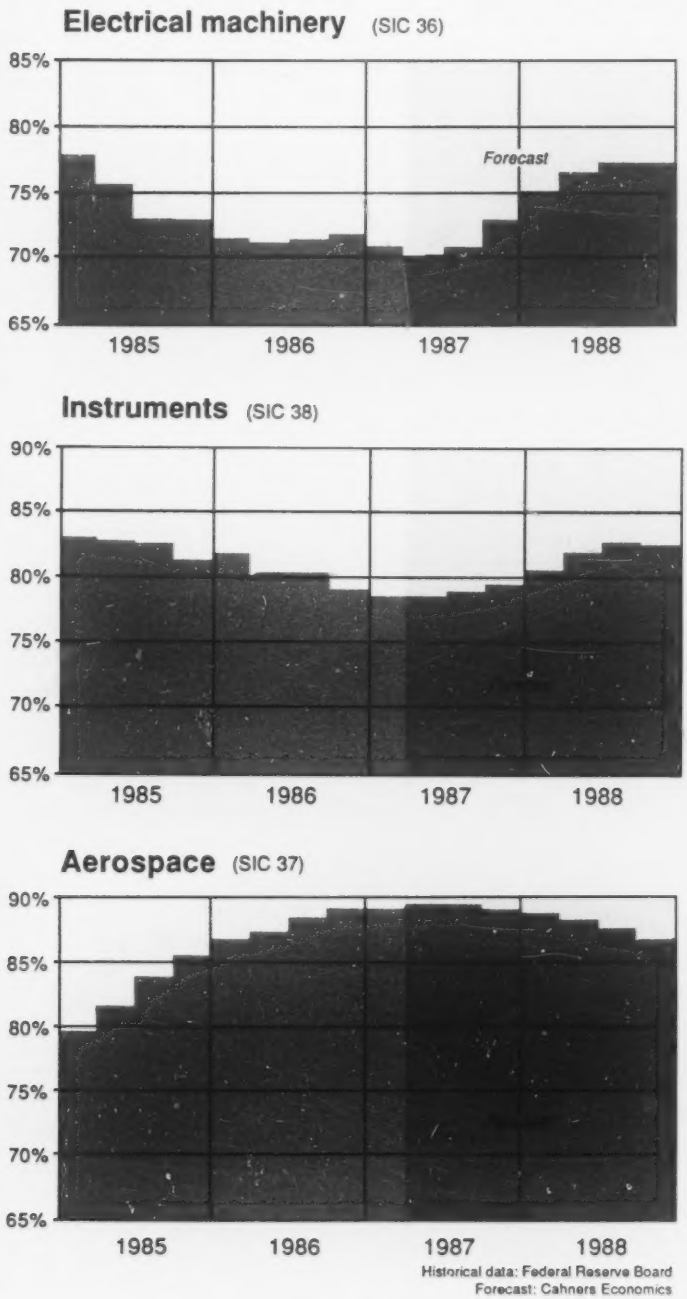
Industrial production indexes, 1977 = 100



Historical data: Federal Reserve Board
Forecast: Cahners Economics

Plant utilization

Average percentage of capacity utilized per quarter



Historical data: Federal Reserve Board
Forecast: Cahners Economics

Electrical machinery

Manufacturers of electrical and electronic machinery operated at 70.8% of capacity in the first quarter, down slightly from a 71.7% rate in the previous three months. Early reports for the second quarter showed continued declines, with the utilization rate dipping below 70% for the first time since March 1983. Although consumer goods markets are sluggish right now, other segments of the industry (including electronic components and telecommunication equipment) have recently entered a growth cycle and are expected to gain momentum in late 1987 and 1988. This should cause operating rates to turn up soon, reaching 72% to 73% by this fall and 77% or higher by the end of next year.

Instruments

In the first quarter of 1987, the factory operating rate in the instrument industry was reduced by one-half of a percentage point to 78.7%. This was the 10th consecutive quarterly decline and brought the rate nearly down to the level of the 1982 low. Because the market for scientific and engineering instruments is affected by trends in U.S. capital spending, it is likely to get a boost from the higher level of planned investments in late 1987 and 1988. Production is expected to quicken after midyear with plant operating rates turning up following nearly three years of decline. Manufacturers will be using approximately 80% of capacity by the end of 1987, with the rate edging up another 3% to 4% during 1988.

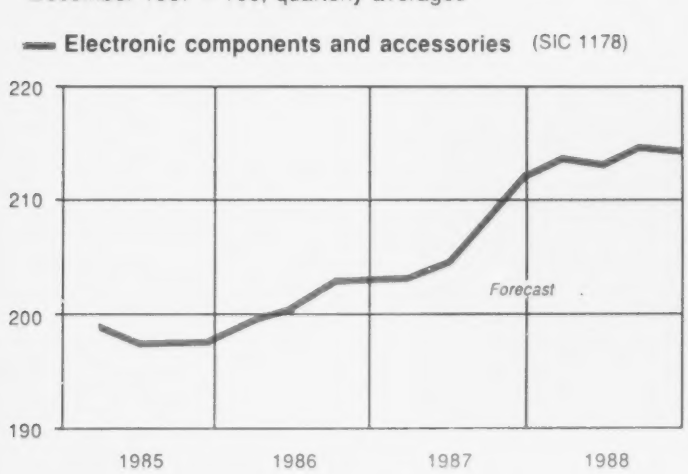
Aerospace

Capacity utilization in the aerospace equipment industries averaged 89% during the first quarter of 1987, unchanged from the level in the previous three months. Preliminary reports for the second quarter suggest that the rate will remain at 89% to 90%, more than 10 percentage points above the average for the entire 1967-1986 period. Although high backlogs will allow manufacturers to maintain about this same operating rate through year-end, the outlook for 1988 is less cheery. The recent squeeze in Department of Defense procurement authority will cause production growth to continue slowing and cause plant utilization to show a gradual decline of nearly three percentage points over the course of next year.

Producer price indexes

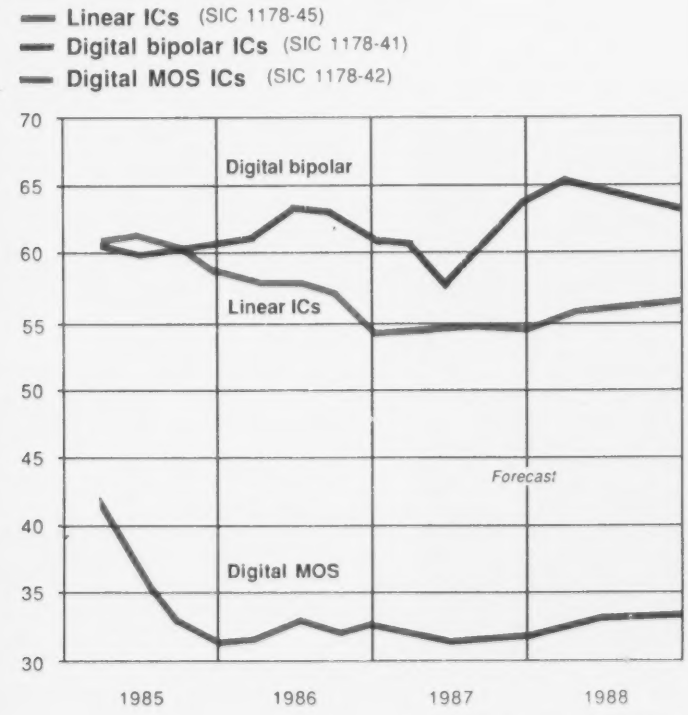
Electronic components

December 1967 = 100, quarterly averages



Integrated circuits

December 1974 = 100, quarterly averages



Historical data: Bureau of Labor Statistics
Forecast: Cahners Economics

Electronic components and accessories

Price trends within the electronic component market were somewhat mixed during the first quarter of 1987. In several product categories, including connectors and resistors, prices edged upward; in others, such as capacitors and some types of semiconductors, they dropped slightly. Industry-wide, prices decreased 0.2% in the first quarter, following an increase of 1.8% for all of 1986. Over the course of this year, as the business recovery gains steam and the U.S. rate of inflation picks up, manufacturers will gradually begin to raise prices. Prices are expected to climb 2.5% this year and 3.5% next year.

Linear ICs

Producer prices for linear ICs, which have been declining gradually since the summer of 1984, continued that trend in early 1987. First-quarter prices were down an average of 1.6% from the previous quarter and were 5.7% below the level in the first three months of 1986. While shipments are expected to register a moderate annual gain of about 12%, prices should not begin to feel corresponding upward pressures until late in the year. As a result, prices are expected to average 4.4% lower in 1987 than in 1986. Look for an overall increase of about 2.5% next year.

Digital bipolar ICs

First-quarter prices of digital bipolar ICs were down 0.8% from the prior quarter and 1.0% from the first quarter of 1986. This was the third consecutive quarterly decline and it pulled prices to the lowest level since the end of 1985. The inventory-fueled recovery that took place in early 1986 brought a temporary wave of price acceleration and the expansion that is now unfolding should result in another, more sustained rise beginning in the second half of this year. Although prices will post an overall annual decrease of 2.4%, they will be much higher at the end of 1987 than at its start. Buyers will encounter tighter supply conditions next year, with prices rising about 5.9% annually.

Digital MOS ICs

Prices of digital MOS ICs tumbled 2.4% in the first quarter of 1987 and are expected to show another decrease of perhaps half that amount, in the second quarter. Despite the softness in prices, demand has shown a solid recovery since last fall. This should translate into mild upward pressure on pricing levels during the second half of 1987 and into early 1988. Prices, which were down 10% for all of 1986, are forecast to edge 1.9% lower this year and then to bound ahead 4.1% next year.

MATERIALS

Why Japan has the corner on the IC materials market

U.S. suppliers may be producing higher quality and more consistent products, but Japan still has the lead

In a market with mature technology, where users are desperate to cut costs, one would think the recent 40% appreciation of the yen against the dollar would give a big boost to U.S. suppliers trying to win back share from the Japanese. But it hasn't helped much, so far, in electronics materials.

Few Japanese suppliers in major materials market sectors have passed through price increases yet. Indeed ,many continue to aggressively slash prices in the scramble for market share in silicon wafers, photomask blanks and leadframes.

"Japanese leadframe makers have cut prices 25% to 30% in the last year," says H. "Nephty" Carter, regional sales manager for Koltron Corp. "Customers tell me our quotes are sometimes double or triple [those of our Japanese competitors]." Koltron is now owned by Nippon Mining Company Ltd.

"My [Japanese] competitors are buying market share," similarly laments Dennis Gobbo, western regional sales manager for Hoya Electronic Corp., major supplier of photomask blanks. "They're selling it for cheaper than I can buy it [from parent company Hoya in Japan]."

Users say they've seen big improvements in quality and consistency from U.S. materials suppliers in the last couple of years, but the Japanese still have the edge.

"Domestic makers are making progress, particularly in packaging materials," says Gary Dean, vice president for materials at National Semiconductor. "They're working on adequate process control, but they still have a ways to go."

> Japanese dominance of the big sectors of the electronics materials market reflects a growing technological edge

Japanese dominance of the big sectors of the electronics materials market reflects a growing technological edge. A recent survey by the Semiconductor Research Corp. consortium's members rated the United States as having a strong lead in all materials, except ceramic packages, in 1981. Last year, however, a majority of survey participants thought the Japanese were significantly ahead in mask blanks, silicon wafers and ceramic packages, and had reached parity in resists, wet chemicals, process gases and molding compounds. Responding companies expected the U.S. to retain parity only in photoresists and process gases by 1991.

One advantage the Japanese have is practically total control of their home market. Hampered by the Japanese perception of U.S. quality problems, few U.S. materials makers have been able to crack the tight existing relationships between the big chip makers and their suppliers.

Monsanto's bid

Even giant Monsanto Co.'s giant effort hasn't come to much yet. Many Japanese industry officials predicted the leading U.S. silicon wafer maker would capture 5% to 10% of the Japanese market this year. The company had made a major investment in Japanese user service and production, and was able to offer wafers at prices reportedly 10% to 40% below its Japanese competitors at a time when chip makers were desperate to shave production costs, and also under great political pressure to buy

Worldwide materials market

Wafer fab materials
($ millions)

	1987	1988	1989
Silicon wafers	$1,265	$1,455	$1,950
Other substrates	115	133	173
Photomasks	885	1,018	1,405
Photoresists			
Negative	71	78	94
Positive	103	120	169
Wet chemicals	258	291	379
Gases	316	363	501
Deposition materials	74	83	144
Total	$3,087	$3,541	$4,815

Packaging materials
($ millions)

	1987	1988	1989
Leadframes	$380	$398	$466
Ceramic packages (metallized)	328	370	455
Thick-film pastes	206	210	231
Encapsulation resins	171	177	211
Bonding wire	173	181	211
Cerdip	156	161	186
Headers and cans	98	98	102
Seal lids	86	108	138
Hybrid substrates (active)	90	95	116
Hybrid packages	84	92	103
Die attach materials	67	75	92
Other	146	158	179
Total	$1,985	$2,123	$2,490

Source: "Electronic Materials Report"

American. But, so far, Monsanto's share of the Japanese market has risen only from about 2% to a little over 3%.

"We definitely see more interest at a top management level," says a company spokesman. "But it's not filtering down to the level of the guy who's doing the purchasing. Our goal of 10% share is probably not realistic. It's probably not realistic to expect the Japanese market to change all its practices and long-standing relationships."

Most of the major Japanese materials producers are still making money, but not much. Operating margins for the major materials producers continue to shrink. Operating earnings as a percent of sales slipped from 12% to 11% at Kyocera Corp. in the most recent fiscal year, from 7% to 6% at Nitto Denko, from 5% to 1% at Toshiba Ceramics, and from 3% to -1% at Osaka Titanium Corp. Hoya, however, managed to maintain 13% operating margins in the last two fiscal years.

A losing proposition

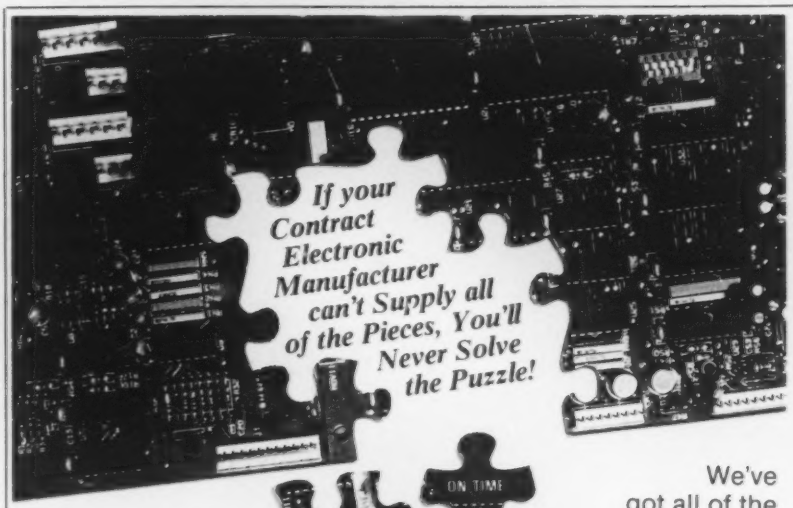
A number of Japanese materials executives admit privately that they are losing money in the United States. One, who asked not to be identified, says that his company's sales are currently much stronger in the United States than in Japan, but the company is losing so much money here that it is considering pulling back and refocusing more of its attention on Japan.

The relatively small and undiversified materials makers are resorting to some drastic cost-cutting steps — like laying off workers. Leadframe maker Mitsui High-Tec cut its permanent workforce by 15% through voluntary resignations and also trimmed 267 part-time workers. OTC reportedly laid off 150 workers, or 10% of the workforce, from its production subsidiary. Kyocera says that its margins improved in the second half of the last fiscal year when it trimmed its workforce by 800, about 6%, by attrition.

Paradoxically, the high yen is likely to drive prices and margins down even further in the near future, as a horde of struggling old-line chemical and metals companies look to electronics materials as their salvation. Kawasaki Steel's expanded NBK, Nippon Steel and Showa Denko are all now sampling silicon wafers to Japanese users, while Toyo Soda holds off production until the market picks up. Kobe Steel and Nisshin Steel are entering the leadframe fray. Kawasaki Steel is pushing aluminum nitride substrates for integrated circuits. Sumitomo Electric Industries is entering the wire-bonding business. Thirteen chemical companies, at last count, had come up with new photoresists using their polymer technology.

"There's going to be huge competition," says Daniel Rose, a Los Altos, Calif., materials consultant and publisher of "Electronic Materials Report." Rose says, "Monsanto and Wacker don't even know what they're in for."

PAULA DOE



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SEMICONDUCTORS

The upstart start-ups

As the semiconductor industry hit new lows, the number of start-ups hit new highs. But is there life after niches?

BY VALERIE RICE

In the Valley, during the most prolonged semiconductor slump that the industry has witnessed, the seeds of the new U.S. chip business were sown. Led by industry veterans often espousing such semiconductor heresies as fabless operations and Spartan surroundings, these companies are beating the start-up survival odds and are making the chip giants rethink their business strategies.

Approximately 130 semiconductor start-ups were formed between 1978 and 1986 and most of them have beaten the odds that half would fail in two years. This surprising survival rate built on the will to succeed is probably the most outstanding quality of this new breed of companies, born during a slump but bred to weather the long term.

Other qualities surface as well. These companies run lean, have aggressive marketing and pricing, and are headed by street-wise executives. All of the company leaders have spent years at large companies; many have done a start-up before. The start-ups are growing so fast that Dataquest Inc. predicts that they will account for nearly $2 billion in semiconductor revenue by the end of this year, up from only $20 million in 1980. But this new breed also has patience — no "short-term growth — damn the consequences" philosophy for these companies. Says Catalyst Semiconductor Inc. president and founder B.K. Marya, "It's all in the attitude. If you want to become a Hewlett-Packard or an IBM Corp., you can't do it instantly. You have to sweat it out."

Of all the start-ups formed over the last nine or 10 years, 75% of them are based in San Jose, California's Silicon Valley region, with the remaining 25% spread out over 12 other national regions, according to a study based at the California State University of San Jose on "New Ventures in the Semiconductor Industry." The study, sponsored by the U.S. Department of Commerce, focuses on the factors of IC start-up success and failure.

THE CLASS OF 1987: (seated, left to right) Weitek's Arthur Collmeyer, Technology's Robert Swanson, Catalyst's B.K. Marya and California

Liane Enkelis

Ten Silicon Valley-based companies — Adaptec Inc., Altera Corp., California Micro Devices Corp., Catalyst, Chips and Technologies Inc., Cypress Semiconductor Corp., Linear Technology Corp., Orbit Semiconductor Inc., Vitelic Corp. and Weitek Corp. — are topflight examples of the new breed. All are currently profitable, all had 1986 sales under $55 million, all are convinced they won't repeat the missteps of their ancestors. These 10 start-ups represent, but don't encompass, the new breed of chip companies. There are many other start-ups that could have been included.

The new semiconductor companies often appear to base their business plans on the premise that those who went before were wrong. Start-up executives, describing

bit's Gary Kennedy and Altera's Rodney Smith; (standing, left to right) Vitelic's Alex Au, Adaptec's John Adler, Linear cro Devices' Chan Desaigoudar

their company origins as "moribund," and "stifling," are determined to create a company where decisions could be made quickly and response times kept to a minimum. And based on the numbers, that strategy seems to be working.

Acid test

One acid test, certainly, is how customers feel about "new breed" products. Ford Motor Co.'s purchasing manager Eugene Greenstein, who admits a distinct reluctance to patronize companies without their own fab facilities, will concede that Ford does use Linear Technology as a supplier because he says that "they supply us with a part we couldn't get anywhere else. It is a quality part and it is very unique." Linear does have its own fabrication facility unlike many of its start-up brethren.

"Focused" is another word that is common to start-ups. These companies exist because they found the chink in the armor of big companies that tried to be a source of one-stop shopping for their customers. This philosophy left a lot of small markets out of the picture, ones that were certainly big enough to attract the attention of small, eager start-ups.

San Jose-based Adaptec, for example, was founded to do just input/output bus boards for personal computers (currently one-third of the firm's business is in chips). These boards are a very narrowly focused area, marketing vice president Jeff Miller says, but one that has stood its ground for the company. "Understanding the silicon was not enough for us," he says. "We had to understand the drives and the systems as well. We supply a niche market, but it is a niche market with our potential customers being everyone who has a disk drive."

Another key element to start-up success, and one that

is common among all of the companies, is the size of the target market. For a small company to take on the world, it had better do so at a level that does not rile the big companies. New companies often choose markets too small for large American or Japanese companies to care about and can thus stay under their "radar" and avoid detection.

San Jose-based Weitek did just that. According to marketing vice president John Rizzo, the company went after that section of the digital signal processing market not dominated by market leader Texas Instruments. Now Weitek predicts that their DSP market segment will grow to between $300 million and $500 miliion in 1987, and it will continue that growth reaching $1.5 billion by the early 1990s. Weitek, by being there first, by being small enough to react to the market, and without the cost pressures associated with a fab, should be able to keep ahead of the market, Rizzo contends. "You've got to keep subdividing the market. Make the niches smaller and smaller. A $1.5 billion dollar market is not one product, it's 100 products," Rizzo says.

Start-up companies also differentiate themselves on the basis of research and development spending. According to one report, the semiconductor industry spends an average of 10.7% of sales on R&D, compared with industry as a whole which only spends 3.1% of sales on R&D. According to the New Ventures study, start-ups (both with and without a fab) have a ratio of R&D dollars to sales of 167% in the first year; 212% in the second year; and 174.75% in the third year.

GARY KENNEDY, (left) president of Orbit Semiconductor; **ARTHUR COLLMEYER,** (center) president of of Weitek; and **B.K. MARYA,** (right) president and chairman of Catalyst Semiconductor

One common theme among most of these companies is the "custom" nature of their products. Reflecting become more vocal and demanding about service and support, and are constantly in the process of reducing their suppliers, small semiconductor companies with customized solutions are in a strong position to reach key, high-margin business from customers demanding solutions.

Says Vitelic marketing vice president Gary Ater: "What pleased the customer in the past pleases him no more today. They are breaking up package-type purchasing [one-stop shopping], and they are demanding uniqueness for their products. Big companies take so much longer to create that uniqueness. The new concept today is small."

To characterize his company's philosophy, Catalyst's Marya calls his products "soft chips," because they are malleable. Catalyst will alter anything to suit a customer's need, Marya claims, and by using words like "soft chips" he hopes to get that message across clearly.

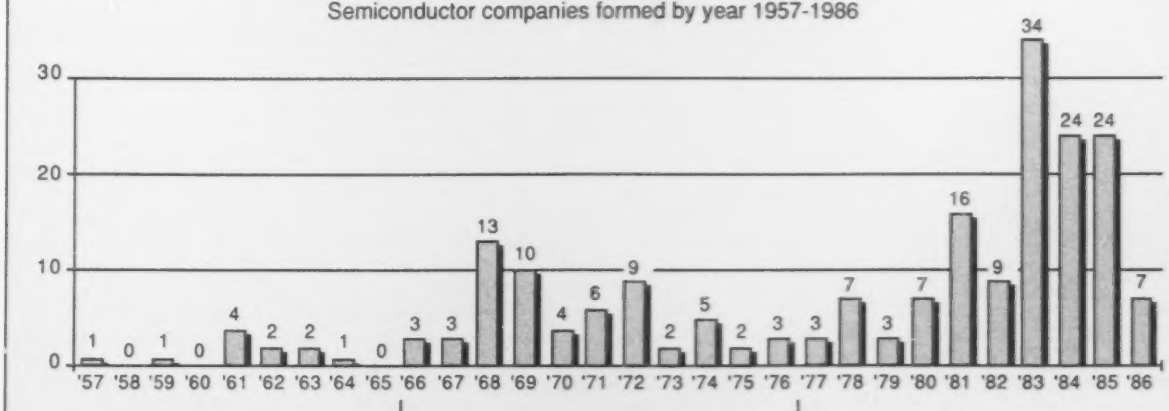
"We do everything for everybody," says Cypress Semiconductor president and founder T.J. Rogers. "We are totally flexible on engineering execution. We do all our manufacturing on any conceivable packaging configuration. Most companies our size have two or three products or even five. We have 74 base products, but over 1,000 variants of those products."

Another key element of start-up success is playing to a company's

Liane Enkelis

The increased start-up pace

Semiconductor companies formed by year 1957-1986



Source: Dataquest Inc.

strengths. For Cypress that meant going after the leading edge in speed and flexibility in high-performance CMOS. For Altera, it meant leveraging their skills and knowledge in the erasable programmable logic device (EPLD) market. For Vitelic, based in San Jose, it was a question of selling their flexibility and strengths in the custom memory area. Chips and Technologies made its mark when it entered the market with an IBM PC AT chip set, really giving the clone market the push it needed to take off and bringing its own growth rate to 76% between 1986 and 1987.

The exception to these rules is Linear Technology. According to Linear president Robert Swanson, not being a digital company breaks all the rules. Unlike other start-ups that can't and don't want to be full service shops, Linear must offer a full slate of analog solutions, and that includes having a fabrication facility of its own. Swanson describes the analog market as a broad sweep of products, customers and needs. "We have to be a broad line supplier," he says. As a result, Linear has a portfolio of 1,200 products which Swanson says "brings a lot of niches together."

But that strategy has worked for the company, which is showing 70% growth over last year, 20% pre-tax margins, and over $1 million in profits for fiscal 1986. "For every $1 in capital investment, we increase sales by $5," Swanson claims.

Orbit Semiconductor also is in a category of its own. Set against both full service houses and the marketing/design houses, Orbit makes a very good living doing foundry work, particularly for low-volume, specialty products.

Orbit president and cofounder Gary Kennedy says that his niche is in "guaranteed turnaround. We have the fastest in the industry," he claims. "The difference is we sell no products. Most every other company has products or service design centers for custom products. We do high-reliability parts in a number of processes. We also have one of the highest prices, but we charge based on value. If we are late, it is 30% less," he says.

Four new breeds

The new breed of start-ups fall into one of four categories, three of which are very different from the traditional semiconductor manufacturing mold.

The first type is a traditional process-driven semiconductor company like a Cypress or a Linear Technology. Both companies have fab capacity, both are trying to push the limits of process technology, and both are full service companies.

JOHN ADLER, (left) president of Adaptec; **ROBERT SWANSON,** (center) president and CEO of Linear Technology; and **ALEX AU,** president and CEO of Vitelic

For some customers, this is still the only type of semiconductor company that will be taken seriously. Ford Motor does not purchase parts from small start-up companies, particularly if they do not have a fab. Says Greenstein; "Who's responsible for quality if there's a problem? We want to deal directly with the manufacturer."

Called value-added distributors or designers (VADs), the second type of semiconductor company is market driven, rather than process driven. They do not have their own fab, but rather use foundry space in other companies' fabs to generate product. Altera, Catalyst, California Micro Devices, Chips and Technologies, Vitelic and Weitek all fall in that category. All of these companies focus on custom or semicustom solutions-oriented products, and all describe themselves as flexible.

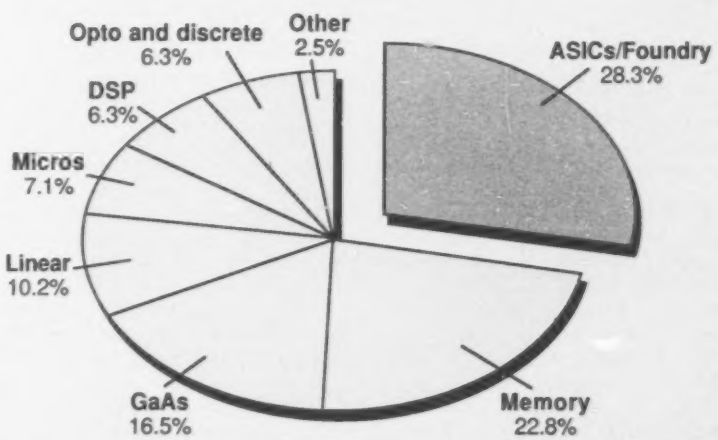
This type is the fastest growing start-up category, and may continue to be for some time, as bottom-line conscious managers struggle to leverage a good product idea with a minimum of investment.

Mountain View, California-based Sun Microsystems Inc. purchasing manager Scott Metcalfe says his company believes in supporting young start-ups, particularly this kind of value-added operation. But, he says, "We worry about the lack of fab capacity. We go to the foundry company directly and negotiate our ability to stay in the queue. We want to make sure they have enough capacity for us in cyclical times."

To illustrate just how sincere Sun's commitment to start-ups is, the com-

Most start-ups are in the ASIC arena

Semiconductor start-ups by market segment



Source: Dataquest Inc.

Liane Enkelis

pany recently signed an agreement with Cypress Semiconductor to jointly develop a high-performance CMOS reduced instruction set computing (RISC) architecture microprocessor.

The third type is the purely service company that does no design but just offers foundry for small volume, high-complexity runs. Orbit Semiconductor is an example of this.

The final type is the vertically integrated company that sells chips and a system or system product, and models itself on the best of the Japanese firms for success. Adaptec, which sells I/O chips and I/O boards using both its own and others' chips, is a vertically integrated company.

Real men have fabs

"You are not a real semiconductor company without a fab," asserts Cypress' Rogers, who has his own fab.

Yet, over two-thirds of these companies lack a fab facility to call their own. Over time, according to the New Ventures study, many of these start-ups build their own. But many companies are staunchly seeking alternate sources.

The biggest advantage Vitelic has over its larger competition, says president Alex Au, is its low overhead and high flexibility because it is not a slave to a fab.

Others agree. "You build a fab and spend your whole life paying for it," says Catalyst's Marya. Catalyst will ultimately have a high reliability, low volume fab, Marya says, but the company will likely never have a high volume fab.

Chips and Technologies president and founder Gordon Campbell never wants a fab, but realizes that ultimately he may have to bite the bullet. The same is true for companies like Altera and Weitek.

But for the time being, these companies are utilizing the high degree of excess fab capacity that exists worldwide. Market research firm In-Stat Inc. estimates that worldwide, fabs are running at between 50% and 65% capacity this year, and much of this capacity exists offshore.

Not surprisingly, then, many of these companies have offshore foundry agreements with European, Japanese, Korean or Taiwanese companies. A relatively few companies have foundry arrangements with U.S. companies, a fact which puzzles and angers some industry pundits who worry about the export of technology offshore.

Campbell points out, however, that small U.S. start-ups often don't have any choice but to make a deal with the Japanese because other U.S. companies are less than receptive. "U.S. semiconductor manufacturers have not gone out of their way to offer subcontracted work," he says. "They are typically not very receptive. The Japanese are very receptive. The only reason they are receptive is that it is

The big guys: In a state of flux

Large companies have really taken it on the chin lately, thanks to the success of the new breed of small semiconductor start-ups.

It is no longer fashionable to be big.

Some of these start-ups, flush with their success, have thrown the gauntlet down, challenging large companies to change the way they do business in order to become more proactive in the market. And, small companies have also alleged that the large semiconductor companies should stop whining about unfair competition and demanding protectionism, and start cleaning their own houses. After all, some of the small companies are beating these guys at their own games.

But are they? There is certainly some evidence that big companies are getting more aggressive and more entrepreneurial in the United States. Consider National Semiconductor's recent deal with Lattice Semiconductor, Beaverton, Ore. That is just one of several deals National has, says semiconductor division executive vice president James Smaha, and the company is looking for as many of these as make sense.

Intel Corp., Santa Clara, Calif., also has several little "in-house spin-offs" under way, says chairman Gordon Moore, and there are funds that exist to continue doing separate spin-offs as necessary.

Motorola Inc. is also rumored to be spinning off a separate group to work on futuristic technology.

This should not be construed as a whole-scale effort to plunge into unknown markets, however. At National, Smaha looks for partners, companies that need what National has to offer, either foundry, money, market access, or any of the three, therefore allowing National to get first rights to leading-edge technology processes without having to invest heavily in them. "Partnerships are a key part of our basic strategy," Smaha says. "We are prepared to do that with big and small companies, on and offshore. Partnerships must be a win/win."

> Big companies are getting more aggressive and more entrepreneurial

At Intel, Moore says that the company has changed over the past years, becoming more market driven and aware of smaller market niches that might have been ignored in the past. In fact, the company is developing several "opportunities" internally, in separate little groups. Two of those opportunities, in fact, are actually housed in separate buildings, in an effort to create more of an entrepreneurial spirit among the engineers. (One of those projects is the PC add-in board, the Above Board, and one is a supercomputer project based on the Hypercube.)

The problem with being a large company today, Moore explains, is that "we have our hands full with the business we have. We have a lot of existing business to tend to. When we are pressured in our existing business areas, it's hard to send our best guys out to do something unless we're sure."

But for the future, National's Smaha warns that there are too many companies in business today, and the market, he says, cannot support 200 semiconductor companies by the year 1990. The start-up momentum will slow down, he hopes, and maybe the pressure he has been feeling will recede. "Five to seven years ago," he says, "this used to be a fun job." □

easier to sell to Japanese companies. The same is true in Europe. It is also cheaper to manufacture."

And by using the advanced process technology available in Japan, Campbell says, a small company can leverage its product base signficantly. "We can stay on the leading edge for free," he says. "We can use whatever technology is best: CMOS, bipolar, BiCMOS. A little company like ours couldn't afford to do all that. There are strong arguments in favor of subcontractors."

Dataquest's Semiconductor Industry Service associate director Mel Thomsen asserts, however, that U.S. companies may have good reason for limiting their inrvolvement with start-ups. Most of the companies, Thomsen theorizes, may already be at work on the same ideas that the start-ups are trying to push, only it takes them much longer to bring them to market.

What about strategic alliance? Clearly the buzzword of the 1980s, strategic alliances would seem to be the answer to a small company's needs. Alliances can provide more than just foundry and can include deals that bring capital, support, new technology and market access, as well as having the added benefit of giving potential customers some reassurance.

Everybody is doing a deal these days, and it does seem as if the Japanese are coming out on top. According to a recent Dataquest study, of the 127 start-ups Dataquest identified in the 1977 to 1985 period, 43 companies have over 70 agreements with Asian companies.

What worries many U.S. players is that small companies, looking for short-term gains, are bargaining the store away. One company with no offshore alliances, the highly profitable Adaptec, says that instead of a sense of nationalism, the company chose to have more control over quality — something only possible with agreements with locally owned and operated companies.

Altera also has an onshore relationship with Intel Corp., Santa Clara, Calif., for EPLD parts. This relationship, says Altera president Rodney Smith, adds credibility to his company, and is a "technology exchange agreement" with no foundry. Altera also recently signed a technology exchange agreement with Cypress for the development of high performance, user-configurable logic products.

RODNEY SMITH, (left) president and CEO of Altera; and **CHAN DESAIGOUDAR,** (right) chairman and CEO of California Micro Devices

In terms of general alliances, data from the New Venture study indicates that start-ups have 1.3 alliances their first year, dwindling to 0.8 alliances by the fifth year. This indicates that the issue is not the number of alliances but one key alliance, New Venture study codirector Claudia Bird Schoonhoven says. These strategic alliances do not include foundry agreements.

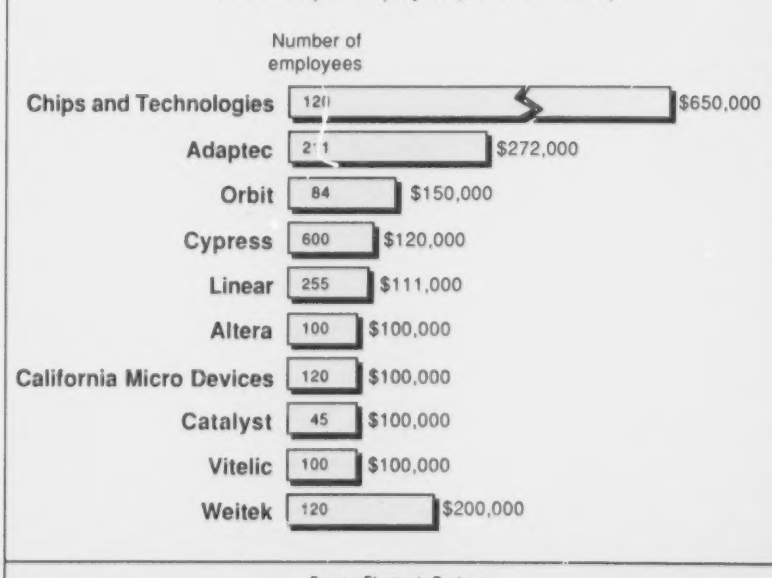
"Management by mavericks," as one executive puts it, has given each start-up company a character that is unique to itself. At Catalyst Semiconductor, time and openness are everything to president and founder Marya. "The CEO's challenge is to keep an open office," he says. "You need more hands-on management." Concerning time: "Time is more important than money to us," he says. "Running out of time is as bad as running out of money."

Altera's Smith says that "technology outstrips demand. Twenty percent of semiconductor start-ups fail. The trick is to establish a foothold in a growing market and look for a flanking move. You are smart to build a barrier and protect yourself so that no one can get at you," Smith says.

"Experience is a two-edged sword," says Weitek president Arthur Collmeyer. "A lot of what you learned about managing a company doesn't apply; it has a shelf life. Experience alone can be a liability. We don't do a semiconductor company the way other people did. Now more companies are doing it the way we do it — without a fab." But, Collmeyer stresses, "the ingredients for success don't change."

The outspoken Rogers of Cypress has a unique theory of management. Rogers claims he "borrows" the best

New breed revenue per employee



Source: Electronic Business

Liane Enkelis

ideas from each of the big semiconductor companies in order to make his company a reflection of all the best parts of the industry. For example, Rogers says that Advanced Micro Devices Inc. is known as a company with good marketing and service, and he has hired people away from AMD to fill those roles at Cypress.

A strange success

The success of these companies may seem strange, given the tumultuous time surrounding their founding. But, according to Dataquest's Thomsen, the best time to start a new business is in a downturn. During this period of time, when product is being developed and strategies are being solidified, everyone else in the industry is worrying about his bottom line, and not looking at new markets.

And venture capital has certainly flourished during the period of 1978 through 1986. According to Dataquest, venture capital available for all high technology firms in 1983 was $3.4 billion, which then dropped to $3.2 billion in 1984 and $2.6 billion in 1985. Stan Bruderle, a Dataquest vice president, says that there were around 35 semiconductor start-ups in 1983 competing for a share of that money, and 25 in 1984. For comparison, Bruderle says that 1986 was a relatively slow start-up year, with only six companies, but those six shared $73.6 million in initial funding.

> Venture capital backing can give a company a strong competitive edge in the market

"What drove the start-up situation was changes in the laws of the U.S. which set up research and development investment tax credits and general ITCs," Bruderle says. "With a limited R&D partnership the investors get a tax advantage or a tax shelter if they invest in new areas. The resulting venture capital was huge, looking for places to be spent."

But according to the New Ventures study, a surprisingly small percentage of start-ups has venture capital funding. In fact, only 50% of semiconductor start-ups have venture capital in their first year, growing to 59% of the total companies by their fourth year in existence (for the period 1978 to 1983), codirector Schoonhoven says.

The relatively small percentage of companies with venture capital probably means some reluctance on the part of executives to give the company away. On the other hand, venture capital backing can give a company a strong competitive edge in the market.

The security of venture capital can also create problems, cautions Campbell. That helping hand of venture capital can give a company a sense of false security, and eliminate the need to watch the costs. Without venture capital, every penny that goes out the door is watched, says California Micro Devices chairman and founder Chan Desaigoudar, who did not have any venture investments.

But for the typical company

LSI's Corrigan: The founding father of the new breed

Many have speculated why Wilfred Corrigan, chairman of Fairchild Corp. during the late 1970s, had to leave the company in order to pursue the application specific integrated circuits (ASICs) business by forming a new company, LSI Logic Corp.

Corrigan, who could certainly be considered the founder of the new breed of companies, says in a nutshell that once a company's culture is formed, it is very difficult to run counter to it, with either product or management ideas, even if you're the chairman.

"You have to go back to the seed," Corrigan says. "Once a company has been in existence for a period of time, it has a culture, and it is difficult to change that."

According to Corrigan, it is difficult to do something revolutionary within a large company. Evolutionary products are relatively easy within a large company, Corrigan claims, but doing something nonevolutionary is nearly impossible. He cites the example of Intel's microprocessor as a revolutionary development that only Motorola was ever able to match. Companies like National and Texas Instruments, he says, have tried but have never succeeded.

"Getting into a totally new area requires a major effort and a lot of focus on the part of a company," he explains. "Typically for a large company it is difficult to critically fund that development when the industry as a whole is facing bad times. From 1981 to 1987 there was only one good period — the latter half of 1983 and all of 1984. The whole rest of the time the majors were under severe financial stress. Their willingness to spend money to start new enterprises wasn't there."

> "Getting into a totally new arena requires a major effort and a lot of focus on the part of the company"
> Wilfred Corrigan of LSI Logic

"At LSI Logic in early 1982 we were burning $300,000 per month at the bottom line. In a large company, we probably would have been shut down or trimmed back because the market wasn't that obvious."

Corrigan likens his experiences at the start-up LSI with being an early, New World explorer. He calls it the Columbus effect. "You know there's something great out there on the other side of the horizon, but the boards of directors are not great believers in the Columbus effect. That's what is meant by *venture* capital."

Smaller companies, then, set sail and have nowhere to go but forward, Corrigan says. And for LSI, the small size and the close relationship to the market made it easy to change course when necessary. "We started as an ECL gate array company, and in less than three months, we discovered that our business plan was OK, but we had the wrong product and the wrong customer base. We had to come up with a totally new product line. Visualize what would happen to a division manager in a large company if he were to change course 12 weeks out. That could only happen in a small company." □

(started between 1978 and 1983) with venture capital, it could raise $6.7 million during its first year, says New Venture's Schoonhoven.

The breed's future

Does the new breed have staying power? They certainly seem to, and a look at the New Ventures data supports this. Says Schoonhoven: "The recession has gone on so long that those who were going to die or be acquired by 1986 have done so. Resources continue to support these companies for a much longer period of time."

Yet, despite a somewhat charmed existence, growth into the next stages may be difficult for some of these companies, particularly those without a fab facility. "Calling these companies the new breed is just falling into the rhetoric," admonishes L.F. Rothschild analyst Paul Johnson. "It's fine to say that they are new and different, but to imply that they won't face the same problems in growth every other company has is very naive. These companies are good but no miracle."

"It's not hard to get to $20 million in sales from nothing," Dataquest's Thomsen says. "The hard part is growing to $100 million and over. What then?"

Rothschild's Johnson says that he hasn't seen that many companies grow above $500 million in this industry. Taking Cypress as an example, he says that for Cypress to grow to $1 billion, it would have to increase its size by 25% every year for 10 years, or to put it in other terms, roughly outgrow the industry by two times every year.

Despite a somewhat charmed existence, growth into the next stages may be difficult for some of these companies, particularly those without a fab facility

Dataquest's Thomsen says the issue really is how a company can finance its growth. Growth is achievable by all of these companies, he said, with or without a fab, but at a certain point, a company must come up with the money to reinvest in order to grow.

That is one reason that right now, Cypress, flush with money from public offerings, has one of the top-line high performance CMOS fabs in the industry, certainly better than most of the major companies, Thomsen says. This is also one reason why Fairchild has had growth problems in the past, he adds: insufficient funds to support needed growth.

And of course, the issue of a fab is seen by many as vital for future growth.

"It appears possible to grow without a fab," says Montgomery Securities general partner Daniel Klesken. "If it's possible, it is the preferred way financially to grow," he says. "The disadvantage is that you don't have total control of your destiny. The factory owner may put you second, third, or fourth on his list."

According to Klesken, a company like Chips and Technologies must ultimately "have some fab under its control," something of which Campbell appears cognizant.

Thomsen also says that a company can't grow without volume, and volume is not achievable without a fab facility of some sort. Low-volume business is good for the short term, but in the long run, a company must achieve high volumes at some level in order to really grow, he says.

Klesken, who feels these companies "have a great future ahead of them," says that future survival is simply a matter of "doing what they've already done. Finding new markets and going out and serving them." □

The return of the metal desk

"Look," he said, pointing with pride, "I have a metal desk."

As it happened, that was Chips and Technologies Inc. president and founder Gordon Campbell speaking; but it could have been almost anyone of the founders of the new breed of start-ups.

It would appear that the new austerity is here to stay, bringing with it a group of people who believe that "less is more" at least as it applies to office furniture.

And despite the seeming frivolity of this issue, there is an underlying seriousness here. Most semiconductor start-ups (all types of start-ups, for that matter) fail because of anticipatory spending. It seems that the new breed has taken heed of that, with a vengeance.

"We have metal desks," Catalyst Semiconductor Inc. president and founder B.K. Marya says. "We have all used office furniture, and only 50% of our people have phones on their desks."

"The first time you do a start-up you have a lot of big company concepts," Campbell says. "In the second start-up you do, you don't do anything that doesn't contribute to your bottom line or your profits. The last place I am going to be putting money is into facilities or anything else like that."

Cypress Semiconductor Corp.'s president and founder T.J. Rogers gets a little defensive on the subject of desks. Rogers, who has a large oak desk in his office, is very quick to point out that only he and three other of his vice presidents have wooden desks, and only because "we have such heavy public contact." Otherwise, as he is quick to prove, the rest of the company sits in cubicals with metal desks. □

Liane Enkelis

RESEARCH & DEVELOPMENT

The top R&D spenders in the electronics industry

R&D spending rose 9.5% last year, led by chip makers and semiconductor-dependent tester companies

By Al Furst and Linda Stallmann

In 1986, Advanced Micro Devices Inc. led the electronics industry in research and development, investing $183.9 million in R&D, or roughly 31.9% of sales.

In an industry where 8% R&D spending is considered the norm, AMD's commitment to new technology strikes some industry experts as incredible. But W. Jerry Sanders, who founded the Sunnyvale, Calif., integrated circuit maker 22 years ago, says he sees nothing wrong with investing in the future, even if it means going into the red.

"If R&D were only 8% of sales, we would have been profitable," Sanders maintains. "But, because our R&D is close to 30% of sales, we lost money." Even so, Sanders says, AMD had no choice.

"If we have evaluated the market for our new products correctly, we have to maintain our level of investment in research and development," he says. "We could keep a tight rein on our capital spending and would not need more cash. But, if we don't invest in R&D, we'd be just relegated to a niche supplier."

Although Sanders may be a little more zealous than most of his counterparts in enthusiasm for new product development, he's not alone in his thinking. Four of the top 10 R&D spenders in the electronics industry last year were chip makers, including Monolithic Memories Inc., a company that AMD is in the process of acquiring. The other two chip makers which made the top 10 in 1986 were Intel Corp., which was No. 2, and National Semiconductor Corp. at No. 8.

Also underscoring the R&D-intensive nature of the microelectronics industry is that two big chip-tester companies, GenRad Inc. and Teradyne Inc., were also represented in the top 10 of our list, as well.

This dedication to research also spilled over into other areas of the electronics industry. As Bernard M. Gordon, chairman and president of 14th-ranked Analogic Corp., points out, "The rate of technological change is occurring at a rate faster than most people can absorb it," forcing many companies to think that they have to invest heavily in engineering, even if, in some cases, productivity suffers.

In all, the 100 biggest research and development spenders in the electronics industry invested $12.9 billion in R&D last year, 9.5% more than the $11.7 billion that these same 100 companies spent in 1985. On a company-by-company basis, this relects an average 8% investment in R&D by the top 100 in 1986, versus a 7.7% average in 1985.

There are, of course, other ways of looking at the data. ELECTRONIC BUSINESS magazine's list of the top R&D spenders is based on an exclusive analysis of the top 100 publicly owned U.S. electronics companies — that is, companies which derived at least 70% of sales from electronics — with over $100 million in sales. However, in addition to looking at the leaders, ranked by R&D as a percentage of sales, it may be also worthwhile to measure how much these companies spent on R&D last year versus the year earlier.

Five companies in the top 100 more than doubled their R&D budgets last year — including workstation vendor Sun Microsystems Inc., electronic warfare specialist Loral Corp., and three disk-drive makers — Maxtor Corp., Micropolis Corp. and MiniScribe Corp.

In terms of sheer R&D spending, IBM spends more on its research and development projects than most companies have sales. □

Top R&D spenders in dollars

Fiscal 1986 figures

Company	R&D expenditures ($ millions)	R&D as a percentage of revenue	R&D rank
IBM	$3,975.0	7.8%	58
Hewlett-Packard	824.0	11.6%	17
DEC	814.1	10.7%	29
Xerox	650.0	6.9%	66
Motorola	492.0	8.4%	52
Unisys	440.8	5.9%	74
GM Hughes Electronics	408.1	3.9%	98
Texas Instruments	406.0	8.2%	53
NCR	320.7	6.6%	69
Control Data	313.9	9.4%	37

Source: ELECTRONIC BUSINESS

Top R&D spenders

Fiscal 1986 figures

Rank 1986	Rank 1985	Company (EB 200 rank)	R&D as a percentage of revenue	R&D expenditures ($ millions)	Change from previous year	Total company revenue ($ millions)	Fiscal year ended
1	6	**Advanced Micro Devices** (71)	31.9%	$183.9	+12.0%	$576.1	3/86
2	8	**Intel** (48)	18.0%	228.3	+16.9%	1,265.0	12/86
3	2	**GenRad** (146)	17.6%	35.9	-20.7%	204.3	12/86
4	14	**Monolithic Memories** (140)	17.2%	35.2	+44.1%	204.9	9/86
5	13	**Teradyne** (100)	16.6%	50.8	+9.4%	306.1	12/86
6	4	**Applied Materials** (178)	16.5%	24.6	-21.9%	149.3	10/86
7	3	**DSC Communications** (102)	15.2%	46.2	-20.0%	304.0	12/86
8	20	**National Semiconductor** (39)	15.0%	222.4	+8.7%	1,478.1	5/86
9	16	**Cray Research** (73)	14.7%	87.7	+78.3%	596.7	12/86
10	15	**Tektronix** (44)	14.6%	198.2	+3.7%	1,357.2	5/86
11	-	**Sun Microsystems** (93)	14.6%	30.6	+101.7%	210.1	6/86
12	18	**Analog Devices** (95)	13.5%	45.3	+18.9%	334.4	10/86
13	-	**Applied Magnetics** (194)	13.2%	17.0	+5.7%	128.1	9/86
14	12	**Analogic** (170)	12.4%	18.4	-0.1%	148.2	7/86
15	7	**Amdahl** (52)	12.3%	119.2	-11.6%	966.3	12/86
16	22	**Avantek** (144)	12.2%	25.4	+20.7%	208.2	12/86
17	26	**Hewlett-Packard** (8)	11.6%	824.0	+20.3%	7,102.0	10/86
18	29	**Fluke** (143)	11.5%	24.1	+7.7%	209.0	9/86
19	-	**Lotus Development** (106)	11.5%	32.5	+53.5%	282.9	12/86
20	9	**Apollo** (86)	11.4%	44.7	+7.5%	391.7	12/86
21	-	**Digital Communications** (176)	11.3%	15.6	+30.1%	137.9	6/86
22	35	**Compugraphic** (92)	11.3%	38.5	-0.4%	341.1	12/86
23	28	**Data General** (46)	11.3%	143.1	+11.4%	1,268.0	9/86
24	19	**Tandem Computers** (60)	11.3%	86.6	+21.0%	767.8	9/86
25	30	**LSI Logic** (151)	11.1%	21.6	+49.5%	194.3	12/86
26	39	**General DataComm** (156)	11.0%	19.6	+15.7%	178.0	9/86
27	31	**Gould** (53)	10.8%	97.9	-32.0%	908.8	12/86
28	62	**Convergent Technologies** (101)	10.7%	32.8	+15.8%	305.8	12/86
29	23	**DEC** (5)	10.7%	814.1	+13.5%	7,590.4	6/86
30	17	**Coherent** (193)	10.7%	14.8	-8.3%	138.2	9/86
31	25	**Prime Computer** (58)	10.7%	91.9	+12.4%	860.2	12/86
32	-	**Microsoft** (114)	10.4%	20.5	+20.0%	197.5	6/86
33	24	**Mentor Graphics** (164)	9.7%	16.8	+15.5%	173.5	12/86
34	27	**Medtronic** (85)	9.6%	38.5	-2.1%	402.8	4/86
35	36	**Intergraph** (72)	9.5%	57.7	+13.9%	605.7	12/86
36	11	**Computervision** (79)	9.4%	46.7	-24.2%	494.7	12/86
37	44	**Control Data** (21)	9.4%	313.9	-0.7%	3,346.7	12/86
38	56	**Gerber Scientific** (139)	9.3%	17.9	+5.9%	191.8	4/86
39	-	**Ashton-Tate** (141)	9.2%	19.5	+72.5%	210.8	1/87
40	53	**Cipher Data** (160)	9.2%	15.1	+14.7%	163.0	6/86
41	57	**Varian** (56)	9.2%	82.3	+12.3%	891.1	9/86
42	-	**ADC Telecommunications** (186)	9.0%	13.0	+9.6%	143.7	10/86
43	-	**UCCEL** (188)	9.0%	12.7	-18.7%	141.6	12/86
44	21	**ISC Systems** (173)	9.0%	14.9	-12.8%	166.1	6/86
45	34	**Storage Technology** (67)	8.9%	62.1	-4.9%	696.0	12/86
46	65	**Western Digital** (89)	8.8%	24.7	+98.6%	279.4	6/86
47	32	**AMP** (40)	8.8%	170.0	+6.3%	1,933.1	12/86
48	73	**Dataproducts** (90)	8.8%	31.0	+0.6%	353.8	3/86
49	63	**Dynatech** (105)	8.6%	22.1	+50.8%	256.7	3/86
50	42	**Spectra-Physics** (142)	8.5%	17.9	+7.4%	210.1	9/8

Source: ELECTRONIC BUSINESS

(continued)

Top R&D spenders (continued)

Fiscal 1986 figures

Rank 1986	Rank 1985	Company (EB 200 rank)	R&D as a percentage of revenue	R&D expenditures ($ millions)	Change from previous year	Total company revenue ($ millions)	Fiscal year ended
51	33	**Micom** (154)	8.4%	$15.9	-15.4%	$189.5	3/86
52	46	**Motorola** (11)	8.4%	492.0	+6.0%	5,888.0	12/86
53	49	**Texas Instruments** (13)	8.2%	406.0	+1.0%	4,974.0	12/86
54	59	**Unitrode** (182)	8.2%	12.2	-2.0%	149.4	1/87
55	55	**Perkin-Elmer** (50)	8.1%	105.0	+6.1%	1,290.6	7/86
56	64	**Altos** (192)	8.0%	10.8	+21.7%	134.2	6/86
57	92	**Tandon** (127)	7.9%	16.8	+36.7%	214.1	9/86
58	68	**IBM** (1)	7.8%	3,975.0	+15.0%	51,250.0	12/86
59	54	**Wang Laboratories** (22)	7.7%	202.8	+12.0%	2,642.5	6/86
60	48	**TIE/communications** (103)	7.7%	22.9	-12.9%	298.2	12/86
61	37	**Paradyne** (112)	7.4%	19.5	-18.6%	261.1	12/86
62	79	**Veeco Instruments** (166)	7.4%	12.3	+39.6%	167.8	9/86
63	47	**Measurex** (152)	7.3%	14.1	-2.6%	192.7	11/86
64	-	**Maxtor** (184)	7.0%	5.9	+100.0%	85.2	3/86
65	43	**Datapoint** (98)	7.0%	22.6	-49.4%	325.2	7/86
66	67	**Xerox** (6)	6.9%	650.0	+7.8%	9,355.0	12/86
67	61	**Andrew** (147)	6.7%	13.3	-16.6%	197.7	9/86
68	98	**Apple Computer** (31)	6.7%	127.8	+76.2%	1,902.0	9/86
69	66	**NCR** (14)	6.6%	320.7	+7.2%	4,881.6	12/86
70	70	**Augat** (113)	6.4%	16.7	-1.8%	260.4	12/86
71	74	**Watkins-Johnson** (118)	6.4%	16.3	+9.2%	255.4	12/86
72	84	**International Rectifier** (177)	6.4%	9.2	+24.3%	145.2	6/86
73	52	**Diasonics** (136)	6.3%	13.7	+12.3%	217.1	12/86
74	-	**Unisys** (7)	5.9%	440.8	+54.6%	7,432.4	12/86
75	88	**M/A-COM** (75)	5.9%	34.0	-20.7%	577.5	9/86
76	71	**Scientific-Atlanta** (81)	5.9%	27.6	-4.8%	469.1	6/86
77	72	**Molex** (91)	5.9%	17.1	+3.0%	291.9	6/86
78	-	**Data Card** (175)	5.8%	9.0	+29.0%	153.6	3/86
79	-	**Atari** (115)	5.6%	14.5	+53.4%	258.1	12/86
80	80	**Aydin** (196)	5.5%	7.6	-0.1%	136.8	12/86
81	94	**Telex** (62)	5.5%	38.3	+55.5%	695.0	3/86
82	-	**Wyse** (131)	5.4%	8.9	+97.3%	166.4	3/86
83	89	**Harris** (29)	5.3%	117.9	+1.9%	2,216.6	6/86
84	78	**Zenith** (34)	5.3%	99.7	+3.9%	1,892.1	12/86
85	-	**Micropolis** (138)	5.2%	11.2	+122.7%	213.1	12/86
86	85	**Decision Industries** (150)	5.2%	10.2	+7.9%	195.1	11/86
87	60	**Kollmorgen** (107)	5.2%	16.6	-27.9%	319.2	12/86
88	86	**General Instrument** (57)	5.2%	41.2	-21.5%	794.3	2/86
89	100	**AST Research** (168)	4.9%	8.4	+67.5%	172.3	6/86
90	-	**Bolt Beranek and Newman** (148)	4.8%	8.6	+50.8%	178.0	6/86
91	75	**Recognition Equipment** (124)	4.8%	11.6	+18.0%	241.8	10/86
92	-	**Loral** (68)	4.7%	30.9	+101.4%	663.8	3/86
93	-	**MiniScribe** (158)	4.6%	8.6	+103.5%	184.9	12/86
94	69	**Honeywell** (12)	4.6%	246.7	-45.3%	5,378.2	12/86
95	-	**Intelligent Systems** (187)	4.6%	5.7	-2.2%	125.5	3/86
96	-	**COMPAQ Computer** (69)	4.3%	26.6	+66.3%	625.2	12/86
97	41	**Seagate** (66)	4.1%	18.9	-2.2%	459.8	6/86
98	-	**GM Hughes Electronics** (4)	3.9%	408.1	+3.9%	10,440.0	12/86
99	-	**Genicom** (174)	3.9%	6.1	+2.3%	157.5	12/86
100	-	**Sun Electric** (169)	3.2%	5.8	+15.8%	177.0	10/86

Source: ELECTRONIC BUSINESS

(continued)

Top R&D spenders by industry segments

Semiconductors

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
Motorola	$492.0	8.4%
Texas Instruments	406.0	8.2%
Intel	228.3	18.0%
National Semiconductor	222.4	15.0%
Advanced Micro Devices	183.9	31.9%
Gould	97.9	10.8%
Analog Devices	45.3	13.5%
General Instrument	41.2	5.2%
Monolithic Memories	35.2	17.2%
Western Digital	24.7	8.8%
LSI Logic	21.6	11.1%
Unitrode	12.2	8.2%
International Rectifier	9.2	6.4%
Total	**$1,819.7**	**10.6%**

Components

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
AMP	$170.0	8.8%
Molex	17.1	5.9%
Augat	16.7	6.4%
Kollmorgen	16.6	5.2%
Total	**$220.4**	**7.9%**

Capital equipment

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
Hewlett-Packard	$824.0	11.6%
Tektronix	198.2	14.6%
Perkin-Elmer	105.0	8.1%
Varian	82.3	9.2%
Teradyne	50.8	16.6%
Computervision	46.7	9.4%
GenRad	35.9	17.6%
Applied Materials	24.6	16.5%
Fluke	24.1	11.5%
Gerber Scientific	17.9	9.3%
Spectra-Physics	17.9	8.5%
Total	**$1,427.4**	**11.5%**

Computer-based systems

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
Hewlett-Packard	$824.0	11.6%
Honeywell	246.7	4.6%
Intergraph	57.7	9.5%
Compugraphic	38.5	11.3%
ISC Systems	14.9	9.0%
Coherent	14.8	10.7%
Measurex	14.1	7.3%
Recognition Equipment	11.6	4.8%
Data Card	9.0	5.8%
Sun Electric	5.8	3.2%
Total	**$1,237.1**	**8.5%**

Microcomputers

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
IBM	$3,975.0	7.8%
Apple	127.8	6.7%
COMPAQ	26.6	4.3%
Atari	14.5	5.6%
Altos	10.8	8.0%
Total	**$4,154.6**	**7.7%**

Minicomputers

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
IBM	$3,975.0	7.8%
Hewlett-Packard	824.0	11.6%
DEC	814.1	10.7%
Data General	143.1	11.3%
Gould	97.9	10.8%
Prime Computer	91.9	10.7%
Tandem Computers	86.6	11.3%
Apollo Computer	44.7	11.4%
Telex	38.3	5.5%
Convergent	32.8	10.7%
Sun Microsystems	30.6	14.6%
Analogic	18.4	12.4%
Total	**$6,197.5**	**8.7%**

Mainframes

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
IBM	$3,975.0	7.8%
Unisys	440.8	5.9%
NCR	320.7	6.6%
Control Data	313.9	9.4%
Amdahl	119.2	12.3%
Cray	87.7	14.7%
Total	**$5,257.3**	**7.7%**

Peripherals

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
Storage Technology	$62.1	8.9%
Dataproducts	31.0	8.8%
Seagate	18.9	4.1%
Applied Magnetics	17.0	13.2%
Tandon	16.8	7.9%
Cipher Data	15.1	9.2%
Micropolis	11.2	5.2%
Decision Industries	10.2	5.2%
Wyse	8.9	5.4%
MiniScribe	8.6	4.6%
AST Research	8.4	4.9%
Genicom	6.1	3.9%
Maxtor	5.9	7.0%
Intelligent Systems	5.7	4.6%
Total	**$226.0**	**6.8%**

Communications

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
Motorola	$492.0	8.4%
DSC Communications	46.2	15.2%
General Instrument	41.2	5.2%
M/A-COM	34.0	5.9%
Scientific-Atlanta	27.6	5.9%
Avantek	25.4	12.2%
TIE/communications	22.9	7.7%
Dynatech	22.1	8.6%
General DataComm	19.6	11.0%
Paradyne	19.5	7.4%
Micom	15.9	8.4%
Digital Communications	15.6	11.3%
Andrew	13.3	6.7%
ADC Telecommunications	13.0	9.0%
Bolt Beranek and Newman	8.6	4.8%
Aydin	7.6	5.5%
Total	**$824.3**	**8.1%**

Government

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
Motorola	$492.0	8.4%
GM Hughes Electronics	408.1	3.9%
Texas Instruments	406.0	8.2%
Honeywell	246.7	4.6%
Harris	117.9	5.3%
Loral	30.9	4.7%
Watkins-Johnson	16.3	6.4%
Total	**$1,717.9**	**5.8%**

Office equipment

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
IBM	$3,975.0	7.8%
Xerox	650.0	6.9%
NCR	320.7	6.6%
Wang Laboratories	202.8	7.7%
Harris	117.9	5.3%
Datapoint	22.6	7.0%
Total	**$5,289.1**	**7.5%**

Software

Company	Fiscal 1986 R&D expenditures ($ millions)	Fiscal 1986 R&D as a percentage of revenue
Lotus Development	$32.5	11.5%
Microsoft	20.5	10.4%
Ashton-Tate	19.5	9.2%
Mentor Graphics	16.8	9.7%
UCCEL	12.7	9.0%
Total	**$102.0**	**10.1%**

Total may not add due to rounding

Source: ELECTRONIC BUSINESS

AUTOMATIC TEST EQUIPMENT

As the chip industry goes, so goes test

ATE vendors are optimistic that sales will continue to build as the U.S. semiconductor industry strengthens

By David Card

After bottoming out of a two-year slump last year, the world market for automatic test equipment is expected to achieve positive growth in 1987. San Jose, Calif., market research firm Prime Data Inc. forecasts 8% growth this year — to over $1.7 billion in sales.

"The dilemma is that the market has gone down for the past two years in a row, so 8% growth is all relative," mourns Prime Data analyst Kenneth Neff. Only a few years ago, sales of ATE to test components and printed circuit boards were growing at a 30% annual clip.

"Our end markets, mired in a slump that began in 1985, have continued to work off the excess capacity they had built up in the heady days of '83 and '84," explains William Thurston, president of ATE maker GenRad Inc. in Concord, Mass. Looking at Prime Data's forecasts, Thurston says his firm expects a rebound but "we're a little more conservative [than Prime Data] — once bitten, twice shy."

Prime Data's Neff, however, says that the general economy has started to pick up. "The Commerce Department has said that there will be 3% growth in capital expenditures this year where it was about flat last year," Neff says. "There are perceptions that the general economic environment is improving." Improving, yes, agrees analyst Stephen Balog of Prudential-Bache Securities Inc. in New York City, but not so fast as to push up ATE sales.

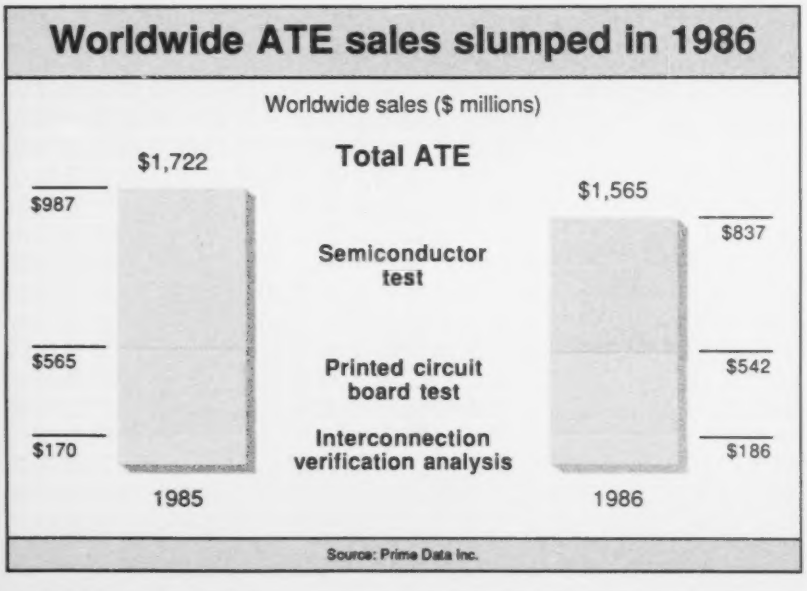
Balog is still waiting. "It doesn't look like, right now, business is booming," he says. "In terms of capital spending, the electronics OEMs certainly haven't turned it on again. It's not clear that business is back by any means."

However, some vendors disagree. James Mulady, director of United States sales and marketing for the Japanese chip test supplier Ando Corp., says "there's no question" that Ando's 1987 sales will be up "15%, maybe 20%. And we look for '88 to be another 15% to 20% — maybe even better," Mulady says.

A good year would also benefit Advantest Corp., the Japanese company that Prime Data ranks No. 1 in semiconductor ATE. Sales went down over 30% last year by Prime Data's reckoning. This does not faze Frederick Bihler, president of Advantest's U.S. operations in Lincolnshire, Ill. A new, ultra high-end tester "should help pick up business," Bihler says. "We made our bet on it."

Even a usually gloomy Alexander d'Arbeloff, president of Boston tester maker Teradyne Inc., is cheering up. "It's a lot more encouraging," d'Arbeloff says. "The semiconductor industry has been up. The word on the West Coast is that people are a lot more optimistic." He thinks 1988 will be a good year. "I believe it. I think the question is: Is there going to be a recovery? If the general economy is even reasonable, the computer business will come out of its shell. There has been confidence building in that industry and that's what has been weak."

"When you have a two-year recession instead of one that lasts six



months, you clean up your balance sheet and idle capacity," says Daniel Pujol, vice president and general manager of Schlumberger Ltd.'s Sentry component tester division in San Jose. That could apply as equally to Sentry as to its customers, Pujol says. After some consolidations of manufacturing — something nearly every ATE company did over the past two years — Sentry has its manufacturing capacity in line with the market, says Pujol. Any time the chip makers are ready to start buying equipment, he says, Sentry is ready to comply. "Generally, when their factories are at around 85% capacity, the semiconductor companies will be investing in capital equipment," he says. "Today, they're at 75% to 80%."

Prime Data's Neff says that for the past couple of years, the only chip-testing equipment that anybody has been buying has been the high-end, engineering machines. "What's encouraging now," Neff says, "is that some production buys are going through."

Meanwhile, chip tester LTX Corp. of Westwood, Mass., would like to see a little more action on the production-buying front. LTX's Trillium subsidiary has been doing quite well selling into engineering applications with its high-end digital tester, but LTX's core linear test business has dragged the company down. "There is a recovery going on, you know," says LTX president Graham Miller. "Korea and Taiwan are doing particularly well," he adds. "The [high value of the] yen encouraged their investment in consumer products."

Even so, the strength of the yen, and to a lesser degree, European currencies, has played havoc with Prime Data's annual ATE sales rankings, complains Neff. "The reality is somewhat skewed," Neff explains. "The perception is that the foreigners did better than the American companies." European business did hold up, he says, much to the benefit of companies like Marconi Instruments Ltd. Still, Neff cautions that if Advantest's results had been reported in dollars rather than in yen, they would have looked much worse.

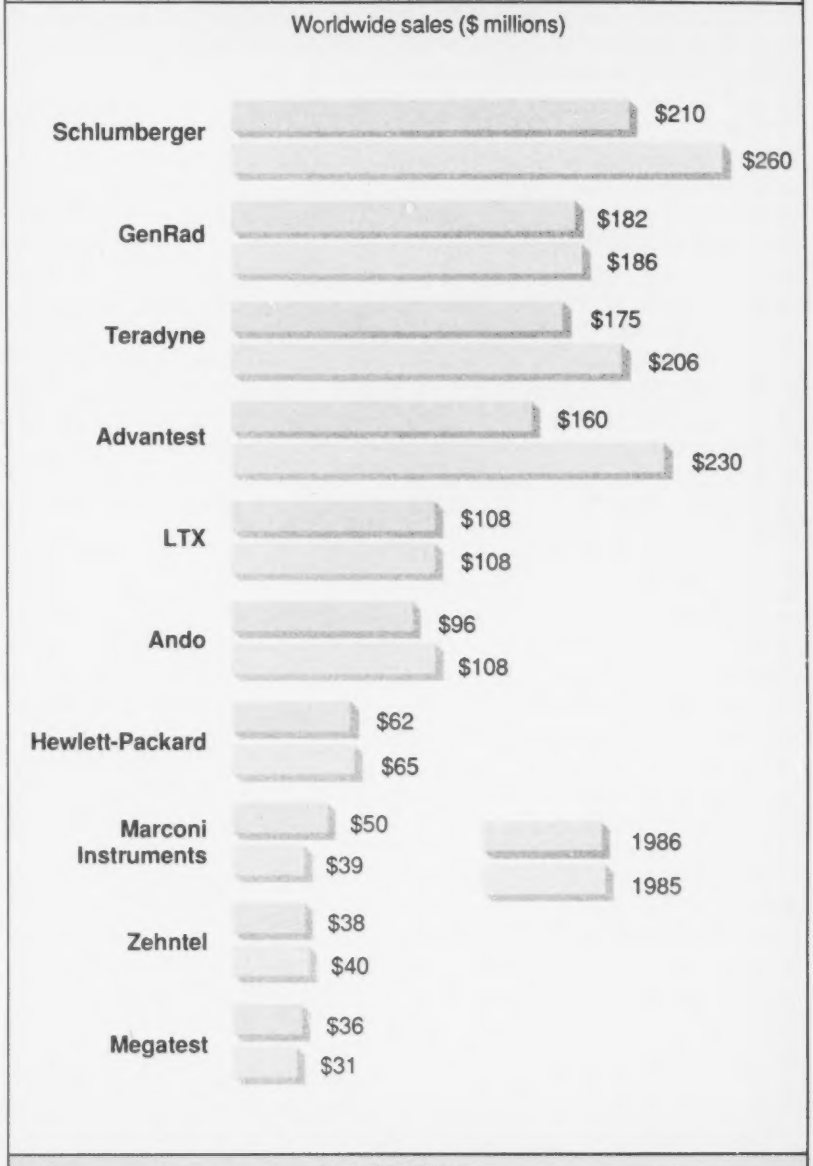
U.S. companies also reported good sales in Europe. Another firm market was military business. Last year it was a stronghold and ATE executives think it should continue that way. "Military business is not booming, but it's OK," says Teradyne's d'Arbeloff.

Both Sentry and Teradyne have new memory testers, but it seems few customers are in the market for them — at least for the time being. Teradyne, realizing the memory chip business had migrated Eastward, has been trying hard for two years to sell its model J937 into Japan. So far, no luck. "We're still holding out," d'Arbeloff says, "We're close enough to selling and it is promising enough that I can say that."

Sentry's Pujol can conceive of two scenarios that would result in a real resurgence of the U.S. memory tester business in five years. One scenario, he says, presupposes that the proposed consortium Sematech is a tremendous success, and U.S. chip makers regain memory dominance. The other has the Japanese losing the memory chip business to South Korea. "As everyone knows," Pujol says, "the Koreans and the Japanese are not in love. They [the Korean companies] would much rather buy an American product.

"Or else," Pujol says, "everything can remain as it is, and the business remains Japan's." He calls that a realistic, but grim, prospect. "We are still in business in Japan, but we are not in the market," he says. Sentry only

Top 10 manufacturers of automatic test equipment



Source: Prime Data Inc.

Automatic test equipment: A graphic look at

DESIGN

CAD for ICs

Calma
Daisy
Seiko

$206 million

CAE

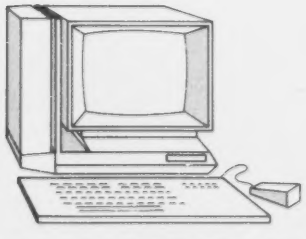
Mentor
Daisy
Valid

$481 million

CAD for PCBs

Racal-Redac
Computervision
Scientific Calculations

$472 million



CHIP PRODUCTION

Engineering and production ATE for components

Advantest
Sentry

$707 million

(Includes memory and linear ICs)

Equipment category

Market leaders

1986 worldwide sales

Total 1986 worldwide ATE sales: $1,565 million

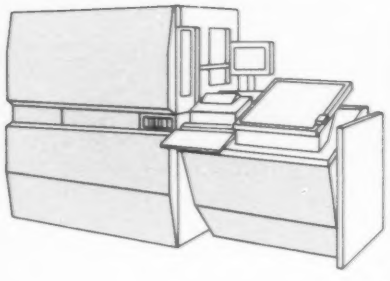
the 1986 market

BOARD PRODUCTION

Production ATE for PCBs

GenRad
FACTRON
Teradyne

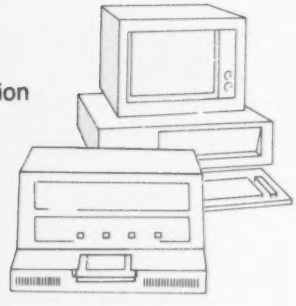
$467 milion



Incoming inspection

Sentry
GenRad

$130 million



Bare board inspection

(Sales included in Interconnection and verification analysis)

Interconnection and verification analysis

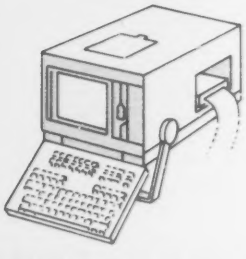
DIT-MCO
Mania
Everett/Charles

$186 million

PRODUCT TEST AND SERVICE

Service and field test

GenRad
Fluke



$75 million

Source: Prime Data Inc.

INTERNATIONAL

China: Poised at an economic crossroads

The Communist Party Congress in October is expected to give some indication of which direction China plans to take

By Al Furst

In two months, the Chinese Communist Party will gather in Beijing to chart the nation's economic plan for the next five years. The October Party Congress will be watched closely by the American electronics industry to determine whether or not China will continue to experiment with free-enterprise management techniques.

In recent months, uncertainty about that country's future economic direction has caused many U.S. companies to reconsider the depth of their commitment to the People's Republic of China (PRC). If China decides to go back to the Russian model of a highly centralized economy, similar to what it did in the 1950s, many multinationals would have a hard time justifying increased investment.

CHINA HOPES TO FIND A GLOBAL MARKET for its black-and-white TVs on sale here in a Beijing department store

Most observers, however, now predict that the faction of so-called reformers, under Deng Xiaoping, will reassert their authority over the ideologues, or hard-liners, at the Congress, making it easier for Americans to do business in China. Newly elected leaders, it is hoped, will press ahead with needed reforms to eliminate red tape, price gouging, excessive taxation and other problems confronting foreigners. U.S. corporations are also hopeful that the Chinese will step up purchases of computer and electronic equipment, even if it means borrowing money from Western banks.

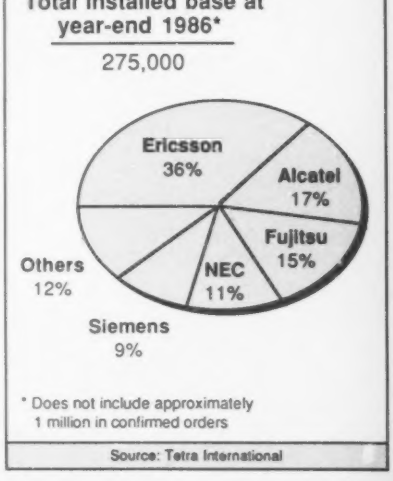
"I'm not a political scientist, I'm just an American businessman," says Louis Woo, the Macao-born business development manager for Apple Computer International. "But from what I've seen of the countryside in China and the cities, from the people, from their standard of living and living quarters, the amount of money they spend and what they spend it on, life has changed dramatically there in the last four or five years. I believe the pendulum of economic reform has now swung over to the extent that it is almost like a point of no return."

Chinese government officials also insist that the "Open Door Policy" which has guided the country since the end of the anarchistic Cultural Revolution will remain open, no matter which faction dominates the Congress. This year, China will import no less than $3 billion worth of electronic, computer and telecommunication equipment, including about $1 billion from the United States, according to Zhang Zhi Dong of the Chinese Ministry of Electronics Industry. Zhang, who heads up the China National Electronics Import and Export Corp. in Stamford, Conn., says that while shortages in hard currency have forced China to be more judicious about the products it buys, it still needs U.S. equipment to modernize if it hopes to compete with Hong Kong, South Korea and Taiwan in consumer electronics.

Consumer electronics

China's goal is to dominate the low end of the consumer electronics market by 1990. While it may take longer than three years to achieve this goal, leading U.S. electronics executives say China's ambitions should not be

The 1986 central office switch market in China



dismissed lightly. "Today we tend to focus on Japan, Taiwan and South Korea," Jerry R. Junkins, president of Texas Instruments Inc., told stockholders at the company's annual meeting earlier this year. But in the future, Junkins said, those three Asian countries will be joined by other "skilled and aggressive international competitors," including the PRC.

John Roach, chairman and president of Tandy Corp. — the largest consumer electronics retailer in United States with more than 7,100 Radio Shack outlets — concurs. "The Orient has developed the engineering and infrastructure skills — in some cases far beyond those you normally find in the U.S. — that support the electronics industry," Roach recently told *Chief Executive* magazine. "The most likely place to see more production in the future, as it begins to develop its economy, is China."

What's interesting about the China market, however, is that the Chinese appear eager to do business with almost any U.S. high-tech company, even relatively small operations. General Scanning Inc., a $20 million manufacturer of galvanometer-based products in Watertown, Mass., for example, recently concluded a $2 million technology-transfer agreement with a manufacturing company in Guangdong Province. The deal, say Wes Davis, president, involves the sale of about 10,000 galvanometers, plus equipment, documentation and training to go along with them. And Geoquest Systems Inc., a privately held Houston manufacturer of computer-based systems for seismic analysis, reports that it is now close to finalizing a deal to sell MicroVAX-based systems to the Ministry of Petroleum. Geoquest said it first made contact with the Ministry through a petroleum industry symposium in Beijing this spring which was cosponsored by MicroVAX manufacturer Digital Equipment Corp.

Despite these numerous small deals, however, it is the larger U.S. firms which continue to be trailblazers in China's market. □

Hewlett-Packard: A major commitment in Beijing

One of the first U.S. companies to play the China card, Hewlett-Packard Co. also claims to be one of the game's more successful players. The company comanages a 250-person joint venture that manufactures small quantities of computers and test equipment in Beijing and oversees the marketing of practically the complete line of HP equipment throughout the People's Republic.

While the joint venture is said to be profitable, the U.S. parent corporation is guarded about the extent to which it has been able to recoup what is reported to be a $5 million investment in the concern.

Nevertheless, HP continues to pour time and money into what one day could become the biggest market for electronic equipment in Asia. To carve market share in the computer field, for example, Hewlett-Packard is now one of the few companies to accept *reminbi* (RMB) as payment for goods sold, according to Francis Tse, the Singapore-based market development manager for HP's Asia/Pacific Technical System Sector in Hong Kong.

RMB, a local currency, can be used by HP to reimburse domestic workers and pay local suppliers — although most of the componentry used in the sweep generators and other equipment HP manufactures in China is imported. Unfortunately for Hewlett-Packard, though, RMB is not recognized by international monetary markets and so therefore cannot be exchanged for dollars, except at an exorbitant discount within China, for repatriation in the form of profits to the United States.

But that's only one of the many hidden expenses HP and other U.S. companies must contend with while doing business in China. Hewlett-Packard, for example, is also investing heavily in training local personnel. One of the toughest challenges, Tse says, is hiring university graduates with electrical engineering degrees to work in sales, marketing and support rather than in the design areas for which they've been trained. These support functions, however, have become increasingly important, as Chinese customers become more sophisticated about computers and other electronic equipment. "The Chinese end user is finding out now that you just don't buy the equipment, and that's the end of it," Tse says.

Nevertheless, Hewlett-Packard has tried to be flexible, Tse says, because "this is not a hit-and-run situation. This is not like the stock market in which you can make a quick buck and then leave," he says. "Oriental culture requires you have patience and [emphasize] long-term relations. That's why Hewlett-Packard in this for the long term." □

Apple Computer: Clones are the core of the problem

Talk about an image problem. Louis Woo, business development manager for Apple Computer International in Hong Kong, has his work cut out for him.

In the early 1980s, Apple clones from Hong Kong, Singapore and Taiwan flooded the the Chinese market. By year-end 1984, International Data Corp. estimated there were about 20,000 "Apple" personal computers (PCs) in operation in China. Even today, Woo believes that 95% of those Apple and Apple-compatible products in China are clones. "There are tens of thousands of them in China today," he says.

Unfortunately for Apple, though, many Chinese users don't make a distinction between true Apples and cheap Apple lookalikes. As a result, Woo says, some Chinese wonder why Apple, "a company which is so famous on an international scale, has come out with a product which is so lousy in China."

To correct these misconceptions, Apple — which did not officially en-

CIRCUIT DESIGN

Simulation: Building a successful design cycle

Big companies have always used simulation to try out a design before going to production. But now the little guys can play too

By David Card

In the electronics time-to-market race, getting there is not half the fun. Being late may cost you your profits. By simulating a circuit design in software, companies can shorten the design cycle — cutting down on prototypes and easing test programming. Big players like IBM and Digital Equipment Corp. have known this for years, but only within the last decade has commercial simulation technology started to trickle down to companies with R&D budgets under a half-billion bucks. Now, everybody can do it.

THE MARKET

Sales of commercial simulation software amount to peanuts compared with what companies spend internally. Still, simulation is "not a bad business to be in," according to Andrew Rappaport of Boston market-watcher The Technology Research Group Inc. Rappaport says worldwide commercial simulator sales will grow over 66% this year, reaching $200 million. Sales could go over $500 million by 1990, Rappaport says. Analyst Kenneth Neff of San Jose, California-based market research firm Prime Data Inc., is much more cautious. He estimates 1986 worldwide sales at about $30 million.

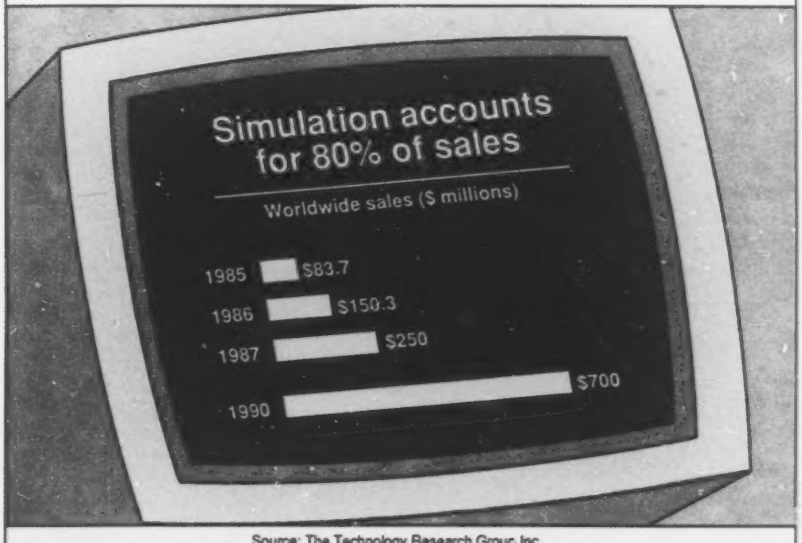
"There is a large installed base of existing simulators among merchant semiconductor makers," says Lutz Henckels, president of simulator maker HHB Systems, "and they will stick to those." Henckels claims to have wooed Sperry Corp. (now part of Unisys Corp.) away from a proprietary simulator, and says Harris Corp. and Martin Marietta Corp. hold corporate licenses from HHB, as well.

The sales of the top three simulators — Cadat from HHB Systems, Hilo from GenRad Inc. and Lasar from Teradyne Inc. — make up 60% to 70% of the market, according to Jeffrey Hotchkiss, general manager of Teradyne's simulator division in Boston. On the contrary, analyst Rappaport contends that those three are outsold by computer-aided engineering companies. Most CAE companies resell either GenRad or HHB simulators, or make their own as do the custom chip houses. Rappaport says simulation is one of the fastest growing CAE segments.

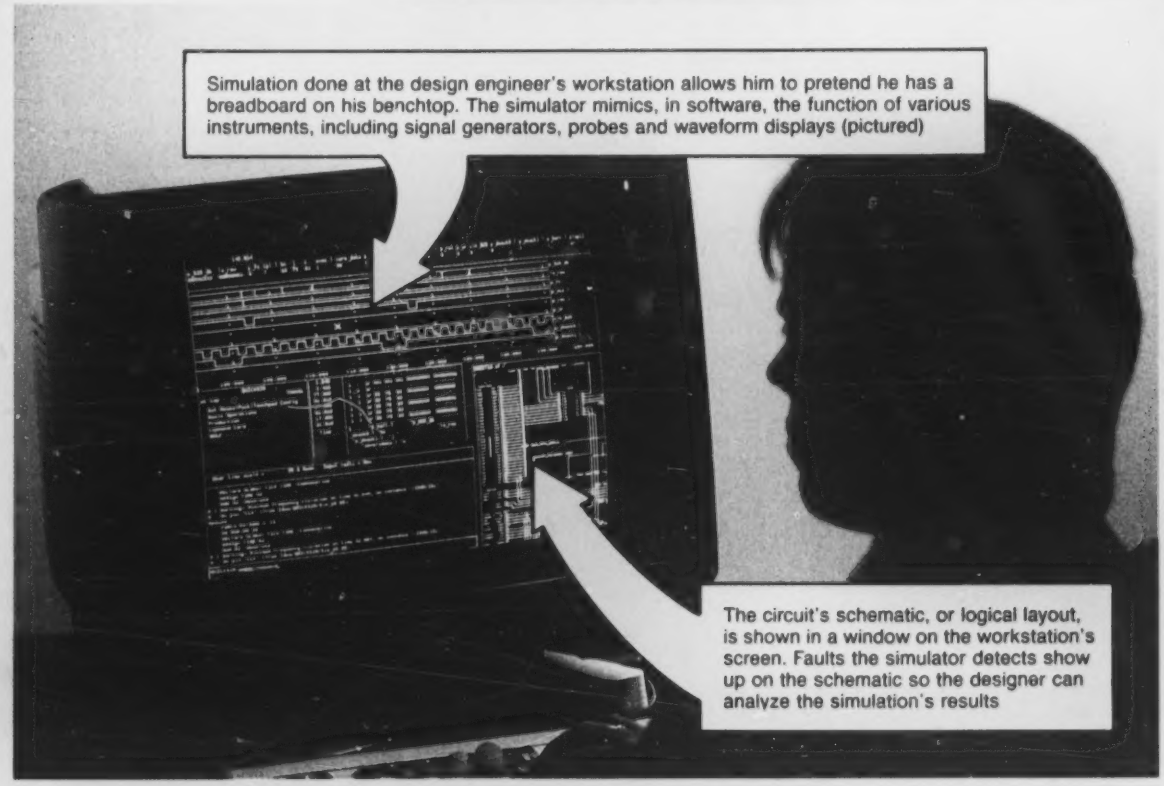
Hotchkiss says Teradyne has two nearby installations at computer companies where over 130 people use Lasar. But, he says, DEC's simulator has hundreds of users and IBM's, thousands. Yet he lists DEC as a Lasar customer, as well. Hotchkiss sees the greatest potential for simulator sales in the board business, rather than semiconductors, if only for the reason that the number of systems designers dwarfs the number of chip designers.

HHB Systems, a private Mahwah, N.J., company, says sales for its 1987 fiscal year, ended in June, were about

Logic and circuit analysis software becomes a big business



Source: The Technology Research Group Inc.


Simulation done at the design engineer's workstation allows him to pretend he has a breadboard on his benchtop. The simulator mimics, in software, the function of various instruments, including signal generators, probes and waveform displays (pictured)
The circuit's schematic, or logical layout, is shown in a window on the workstation's screen. Faults the simulator detects show up on the schematic so the designer can analyze the simulation's results

Photograph Dilip Chauhan, Computer Courtesy Apollo Computer

Mimicking circuits in software

The theory is, that by simulating at the design stage, companies can avoid building costly prototypes or "breadboards." Prototypes are expensive enough in terms of money but, more important, in time to market. The practice is, well, every little bit helps.

"We still prototype. You really can't eliminate that," says Richard Bushroe, director of computer-aided engineering at Apollo Computer Inc. Apollo does about as much simulation as anybody. "The object is to release the product with no redesigns, and simulation is the only way to do that," Bushroe says. It is not unreasonable for Apollo to reduce the time spent debugging prototypes by over 45% via simulation.

In electronics, there are two basic types of simulation: logic and fault. Logic simulators analyze the behavior of a design by exercising a software model of the physical chip or board. Fault simulators run potential errors through that model, checking the model and providing information useful in the development of programs for automatic test equipment (ATE).

Simulators behave at various levels of electrical and logical function. At the transistor level, the simulator looks at what is happening electrically in the circuit — how signals are spreading and which switches are switching. At higher levels, physical functions are modeled according to probability and manipulated by software algorithms.

As an adjunct to board simulation, a market for software models of popular commercial chips is emerging. Also, so-called hardware modelers allow actual chips to be plugged into a simulator. And finally, true system simulation is within range. IBM, say, could give third-party software companies a jump on the market. By getting ahold of the simulation of IBM's latest PC, they could start to write applications software for the machine before it was finished. □

$13 million, with $2.9 million in profits, according to Henckels. GenRad's simulator sales hit $7.5 million last year, up 25%, "... and last year was supposed to be a down year," says Peter Denyer, marketing manager for GenRad's simulator products. GenRad's simulator division operates out of Fareham, England.

"It's a very fragmented market," says Andrew Haines, strategic marketing manager for application-specific integrated circuits (ASICs) at VLSI Technology Inc. in San Jose. VLSI Technology, like most custom chip houses, markets its own proprietary simulator, but must remain friendly to other ones. Haines estimates that there are over 100 commercially available simulators.

The proprietary simulators generally run on big computers — mainframes or networked superminis made by whichever big computer company is using it. Apple Computer Inc. reportedly bought a Cray Research Inc. supercomputer for the purpose of system simulation. The new breed of minisupercomputer makers, many taking advantage of parallel-processing technology, are eyeing the simulation market hungrily.

But there is already an established hardware market — computers opti-

(Continued)

mized to run the lengthy simulation programs. There are a number of companies offering these accelerators, but Zycad Corp. of St. Paul, Minn., is king. Zycad president John Fahlberg says last year's market for big accelerators (other companies make board-level boosters) was worth $30 million, with Zycad accounting for $25 million. Fahlberg thinks the market could reach $200 million by the 1990s.

JOHN FAHLBERG, Zycad's president: The market for accelerators could reach $200 million by the 1990s

COST OF ENTRY

The cost of using simulation is not really a consideration, contends Richard Bushroe, director of Apollo Computer Inc.'s internal CAE operations in Chelmsford, Mass. Apollo makes 32-bit engineering workstations, and its market is highly competitive and fast growing. As an example of just how fast that market is, Apollo, after shipping its first computer in 1981, had completely revamped its product line by 1986. The same thing should happen every two or three years, Bushroe estimates.

Apollo is a serious user of simulation. It has about 150 hardware designers, half of whom do simulation in any given day. Another half of its diagnostics team of 20 simulate test cases for software development. Apollo uses simulators from many sources, including: chip simulators from CAE vendor Mentor Graphics Corp. of Beaverton, Ore., and chip maker LSI Logic Corp. of Milpitas, Calif.; board and subsystem simulators from Aida Corp. of Santa Clara, Calif., and Gateway Design Automation Corp. of Westford, Mass.; and a system for microcode development from Endot Inc. of Cleveland. Apollo also uses a Zycad accelerator and board-level accelerators from Aida.

Still, Bushroe estimates that simulation takes only a fraction of Apollo's $44.7 million R&D budget, well under 10%. Bushroe does not justify simulation on savings. "It's not because of the cost," he says, "it's because you can't do designs that are state of the art unless you have these tools. You can't get to market in time, especially with the competitiveness the way it is. The justification is not with savings, it is because it is absolutely necessary to get the job done."

In general, simulators run about $20,000 to $35,000 per workstation license. Licenses for bigger computers cost more, but the breakdown to per-seat considerations is about the same.

If you want to build your own simulator, it can be done. HHB originally spun out of GenRad's simulator operations back in 1975. HHB survived as a consulting firm for simulation and test programming, writing a simulator for Siemens AG in 1982. That deal was worth about $7 million. In 1983 HHB introduced Cadat, then booked a first round of financing worth $1 million. Since then, the company has made a living on Cadat, with a little $5 million help from Schlumberger Ltd. At press time, HHB was in the process of closing a second round of venture capital in the $4 million range.

Gateway Design president Prabhu Goel worked at IBM's East Fishkill, N.Y., chip facility, then at Wang Laboratories Inc. before founding his company. He claims to have written his first simulator on a rented Radio Shack computer. At VLSI Technology, they are a little more traditional. ASIC marketing manager Haines says VLSI Technology has about six or seven man-years worth of effort in its logic simulator. The total cost was around three-quarters of a million dollars.

RICHARD BUSHROE, director of Apollo Computer Inc.'s internal CAE operations: The justification for simulation "is not with savings, it is because it is absolutley necessary to get the job done"

THE COMPETITION

"Our simulator is 5 years old, going on 6," Haines says. "We are loath to go to somebody else's simulator and start the process all over again." That is part of the reason the market is competitive. Haines adds that any physical design tools are dependent on a particular chip maker's manufacturing process. The same, to a degree, could be said for simulators.

"We can't pretend we're not in the business," Haines says. The nonrecurring engineering costs of custom chips, which include simulation,

Dilip Chauhan

RICHARD ROGERS, GenRad's chief operating offic[illegible]e don't sell Hilo to make money through those programs, but to sell testers"

make up 40% of ASIC sales, Haines says. "We can't give simulation away because only 25% to 50% of all chip designs actually go into production."

ASIC foundries are rated on the strength of their silicon compilers, their physical layout tools and their simulators, says Daniel Pujol, general manager of Schlumberger's chip tester division, Sentry, in San Jose. "They will never share that with outsiders," he says. Hence, Schlumberger's investment in HHB. Actually, sharing is a relative term. Both VLSI Technology and, recently, LSI Logic, sell a subset of their design and simulation tools.

The two test companies could not have more dissimilar strategies for marketing their simulators. Teradyne sells Lasar itself, along with a parallel-processor computer from Sequent Computer Systems Inc. of Beaverton. Teradyne also sells a CAE package from Viewlogic Systems Inc. of Marlborough, Mass. "Teradyne's trying to position themselves as a one-stop shop, turnkey CAE vendor," guesses GenRad's Denyer. "They're playing on somebody else's hill. I try to stay on a hill I can defend."

GenRad has gone the other route, licensing Hilo on an original equipment manufacturing basis to such potential big hitters in CAE as Hewlett-Packard Co., Intergraph Corp. and Tektronix Inc. GenRad also sells direct. "Actually, the sales through the OEM channel have not been significant," says GenRad chief operating officer Richard Rogers. "We're leveraging the penetration of Hilo. We don't sell Hilo to make money through those programs, but to sell testers."

In direct contrast, Teradyne's Hotchkiss says: "My charter is to be successful within design, independent of the test business.... My success is measured by how well we do against Daisy, Mentor and Valid, not how many testers we sell." Daisy Systems Corp., Mentor and Valid Logic Systems Inc. are the three CAE market leaders.

Hotchkiss admits that the original reason for offering a simulator — Teradyne bought an LTV Corp. simulation spin-off, Digitest, in 1972 — was for test. Certain circuit-board test equipment is notoriously difficult to program, he says. Simulators produce data useful in programming, and give a design-to-test link craved by ATE companies "GenRad began to get more market share with Caps," an early simulator, Hotchkiss says. "Lasar was a defensive move."

Now, simulation has become a strategic issue. The simulator "is the core analysis tool of a designer," Hotchkiss contends. Teradyne has to either "control it, or get designed out of the process." Hotchkiss thinks GenRad's strategy is the risky one, as it could lose control of Hilo to its OEMs. "I'd be amazed if they don't bring out their own simulators," he says. He points to an ill-fated deal between HHB and Mentor as a case study.

HHB originally sold a chunk of Cadat to Mentor, which Mentor evolved into its own, competitive simulator. HHB's Henckels calls that deal a "screw up" that he will not let happen again. From now on, the code stays home. Even with that lesson, the battle for OEMs is pretty ferocious. Henckels gloats that he recently stole Computervision Corp. away from GenRad. GenRad's Rogers retorts: "If we lost HP or Tek, I'd be worried."

Another Beaverton start-up, Analogy Inc., picked its market accordingly. President R. Larry Jacob aims his simulator specifically on analog circuits, rather than the fierce digital market. "We focused on analog boards because there was no competition," Jacob says. He has signed up CAE board specialists Cadnetix Corp. and Racal-Redac Ltd. as OEMs.

THE OBSTACLES

To feed a board simulator, companies must have access to detailed models of the chips that will populate it. The problem is, Motorola Inc. does not want the heart of its latest microprocessor's functionality to fall into the hands of Intel Corp., or vice versa.

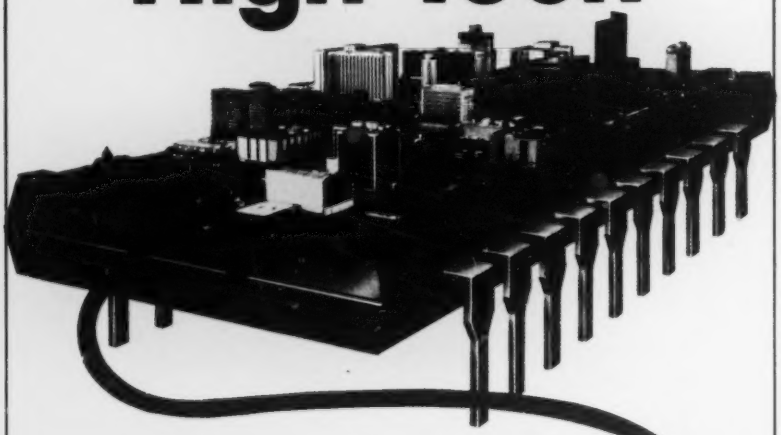
Building a model is no fun. Apollo's Bushroe says that it could take up to two years to develop a software model for Motorola's 68020, the heart of Apollo's workstations. Apollo gets around that by using Mentor's hardware modeler, which allows an actual 68020 to be plugged into the simulator.

Still, not every chip is covered. The accurate timing measurements crucial to a chip model do not come with the catalog, says HHB's Henckels. "To be blessed with those costs $400,000," from, for example, LSI Logic, he says. Adds VLSI Technology's Haines: "Nobody wants to write models for the Intel 8086 or the 80386. We don't want to do it."

Fortunately, somebody does. Apollo buys models from Beaverton's Logic Automation, and Quadtree of Bridgewater, N.J. "These companies open up a whole new area of business for our type of companies," says Gateway Design's Goel. "Now, there can be tremendous growth in card, board and system simulation." Gateway has deals with both Logic Automation and Quadtree. Quadtree just introduced a service that president Roger Hobbs says can automatically

Henry Wilhelm

Link Up With High Tech



Considering relocation or expansion in the increasingly competitive high technology industry? Make all the right connections in the Las Vegas Valley.

Companies like Ford Aerospace and Aerojet Nevada have already linked up with Las Vegas and for some very good reasons.

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generate models from a chip's data sheet.

The hardware limitations are fading also. In fact, they may be fading the business opportunity away. Apollo uses Mentor's accelerator, and for really big designs, a $1 million machine from Zycad. But Bushroe says: "As time went on, tools like Aida's came along." Aida makes a plug-in board for Apollo workstations to speed up its simulator. It priced Zycad right out of the market, according to Bushroe.

In addition to that, the simulators are getting more clever. Gateway Design's Goel claims his does not need an accelerator. It can run efficiently on a workstation because it does not bother to simulate every single event sequentially. For example, if a particular signal does not affect a particular gate, the simulator recognizes that and skips over that gate. "From a business standpoint, hardware accelerators are going to have a hard time competing," Goel says. "At any given time they can reduce the algorithm to hardware and gain a quantum jump in performance. But they can't maintain that jump."

Mentor has as much as acknowledged that argument. "We're not going to invest heavily on that in the future," Mentor president Gerard Langeler says of his accelerator. Instead, Mentor will rely on Apollo keeping up in the computer performance race. Mentor also just signed a deal to resell Zycad accelerators.

Zycad, of course, takes a different point of view. "Even though there will be more parallel-processing MIPS [millions of instructions per second, a popular way of gauging processing speed], and even 30-MIPS workstations, our customers say that's just not going to hack it," president Fahlberg says. "At five [thousand] to 10 thousand gates, all of a sudden you have a simulation bottleneck," he says.

Zycad has gotten its price down: it now offers a variety of price/performance boundaries. But one way it did it was by buying out a competitor, Silicon Solutions, of Menlo Park, Calif. Zycad had to swallow $12 million in merger costs, and suffered a layoff and the resignation of its president. Zycad dumped a program to build a board-level accelerator, Fahlberg says. Still, the market is interesting enough to sponsor another start-up, XCAT Inc. of Hopkins, Minn. □